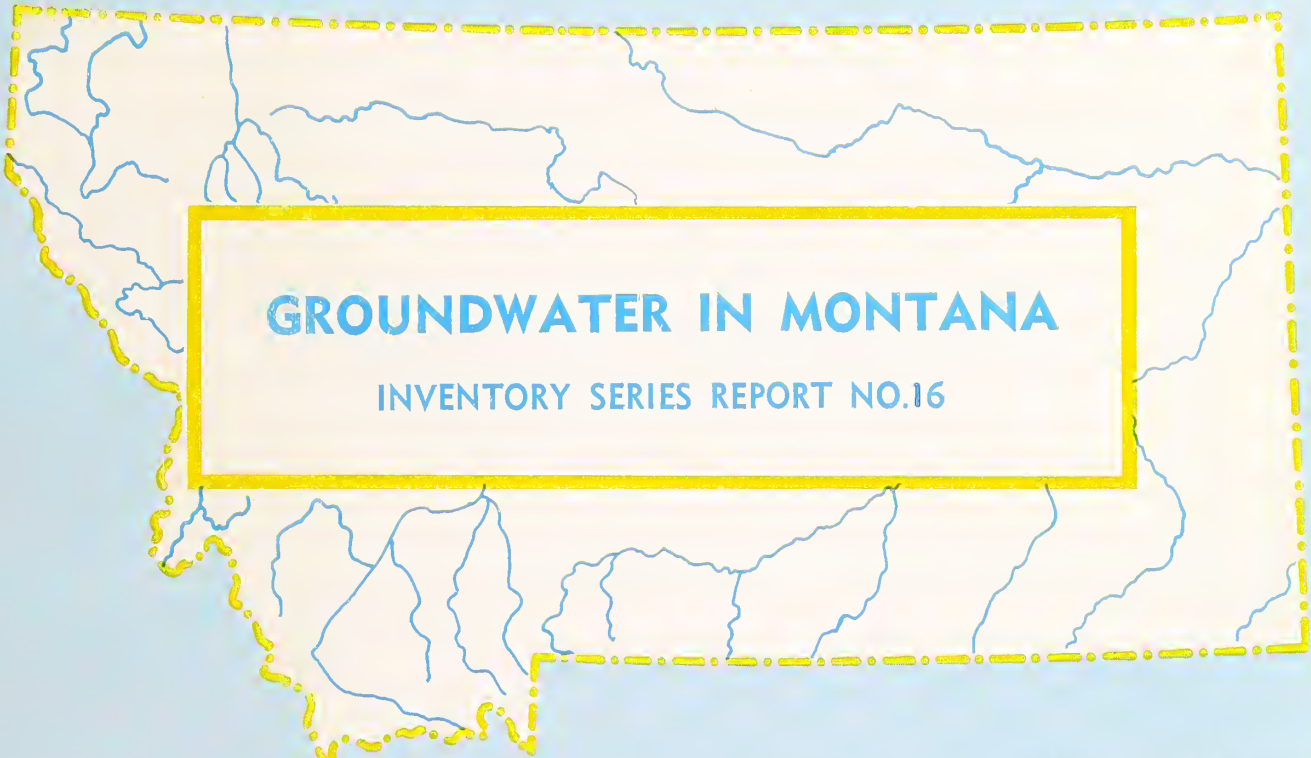
"A Comprehensive Water and Related Land Resources Plan for the State of Montana"



GROUNDWATER IN MONTANA

INVENTORY SERIES REPORT NO. 16

MONTANA WATER RESOURCES BOARD

Sam W. Mitchell Building
Helena, Montana

STATE OF MONTANA

MONTANA WATER RESOURCES BOARD

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NOVEMBER, 1969

The work upon which this report is based was supported primarily by funds provided by the Montana Legislature and with funds furnished by the Water Resources Council under Title III of the Water Resources Planning Act of 1965 (Public Law 89-80).

3 REPORTER PRTG. & SUPPLY CO.

FOREWORD

June 1970

Dear Fellow Montanans:

This report "Groundwater in Montana," was initiated by the Montana Water Resources Board as part of the inventory phase of our Comprehensive State Water Plan. The study was prepared by the Montana Bureau of Mines and Geology under a contract with the Montana Water Resources Board. Credit should also be given to the Bureau's geologist, Mr. Miller Hansen, principal investigator and author of this publication and to the U. S. Geological Survey which aided in compiling the data.

This is the most substantial effort to date to estimate the quantity of groundwater within the state and should assist in determining future planning emphasis.

We sincerely believe this report, and the entire inventory series, can be of significant benefit to the people of Montana in laying comprehensive groundwork for a growing state.

DOUGLAS G. SMITH

Director

Groundwater In Montana

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GROUNDWATER IN MONTANA

ABSTRACT

Published groundwater reports and other reports containing information required in estimating availability of groundwater in Montana, were reviewed, summarized, and compiled into one publication.

The unconsolidated aquifer summaries provide information that includes aquifer area, thickness, specific yield, groundwater in storage, perennial recharge, and water quality in each report area. The unconsolidated aquifers are grouped by drainage basins in this compilation.

Yields in excess of 1,000 gpm of good quality water are produced from unconsolidated aquifers at several localities in Montana.

Abandoned preglacial and temporary glacial channel aquifers are reviewed in a separate section. Wells in these channels produce potable water at rates in excess of 250 gpm at several locations.

The bedrock aquifers are presented separately with a discussion of the availability of groundwater from each formation. Maps showing the outcrop area of the formation and generalized outlines of the areas in which well locations are known from published records, were prepared for the Fort Union, Hell Creek-Fox Hills, Judith River, and Kootenai formations. The range of well depths, water table levels, well yields, and water quality is listed for each of the well areas.

A generalized list of stratigraphic units shows the hydrologic characteristics of both the unconsolidated and the bedrock aquifers.

In general, wells in the bedrock aquifers produce small to moderate yields of good to fair quality water. Aquifers in the Kootenai in Wheatland County have a potential in excess of 1,000 gpm and the Chugwater, Tensleep, Amsden and Madison provide flows in excess of 1,000 gpm in portions of Big Horn and Carbon Counties.

In the unconsolidated aquifers considered in this report it is estimated that more than 10 million acre-feet of water is in storage and available to wells. Perennial recharge, the amount of water available for development on an annual basis without depleting storage, is estimated in excess of 1,300,000 acre-feet. No quantities were computed for storage and recharge in the bedrock aquifers.

More than 42,000 wells and 18,000 springs in both the unconsolidated and in the bedrock aquifers are recorded under the provisions of Montana water laws. Springs are of considerable importance in Montana for domestic, stock, municipal, and irrigation water. An important use of springs is shown by the location of fish hatcheries at several springs in the State.

The quality of groundwater is generally excellent to good in western Montana, excellent to fair in central Montana, and good to poor in the eastern part of the state.

Much groundwater information has been assembled in Montana, but vast areas are essentially untested. Plans already projected by the Montana Water Resources Board call for early investigations in areas where groundwater data is still needed.

INTRODUCTION

Groundwater resource investigations in Montana have been conducted since the days of the early settlers. Publication of reports on groundwater resources began in 1909 with a study by the United States Geological Survey of surface water as well as groundwater in a large area around Great Falls. Various agencies of the State and Federal government have been responsible for preparing and publishing groundwater studies, and of these, the most prominent are the Montana Bureau of Mines and Geology, and the United States Geological Survey. Considerable information is also available from the Water Resources Surveys of the Montana Water Resources Board.

It is recognized that no clear line can be drawn between surface and groundwater. Groundwater reservoirs are recharged mainly by precipitation, stream flow and irrigation water. Conversely, during the dry months, stream flow is maintained largely by groundwater discharge.

The Montana Water Resources Board decided that one publication containing a summary of groundwater data would be advantageous in planning for future development of groundwater resources in Montana. Consequently, this report was compiled, chiefly from information in previous groundwater publications, but supplemented by data from the Water Resources Surveys of the Montana Water Resources Board, Montana Highway Department test hole logs, and various other sources. This report was specifically prepared to provide a convenient reference to data for formulating a State Water Plan.

Acknowledgements

The assistance of all those directly connected with this project is gratefully acknowledged. Dr. George B. Maxey, consultant, Montana Water Resources Board, provided much valuable assistance as did Mr. Charles Lane and Mr. Gale McMurtrey of the U. S. Geological Survey. Dr. S. L. Groff of the Montana Bureau of Mines and Geology helped with the original planning for the project and provided a great deal of background information. Dr. Maxwell Botz and Mr. Marvin Miller of the same organization aided with technical advice.

I am especially indebted to Mr. Donald L. Coffin, U. S. Geological Survey, for general assistance, discussion of problems, and for his careful review of the compilation.

EXPLANATION OF CHARTS AND AREA SUMMARIES

Groundwater information compiled from various Montana publications is presented in this report in area summaries and on charts. As many as four items are listed in the same column on the charts so that the data can be presented on two facing pages. The information in each of the area summaries also appears on two facing pages.

Only data referring to the unconsolidated aquifers in alluvium and terraces are shown on the area summaries and on the charts. The bedrock aquifers are presented in another section of the report with maps and areal descriptions.

In some instances two or more reports cover essentially the same area. Only one report is listed as a reference on the chart, but all are shown on the individual area summaries.

If the area of the aquifer is given in the report, this figure is used on the chart and in the area summary. Otherwise, the area of the aquifer has been obtained by the compiler from other reports such as the Water Resources Surveys of the Montana Water Resources Board or determined from U. S. Geological Survey geologic or topographic maps.

Similarly, if figures for specific yield, aquifer thickness, storage, and recharge are provided in original publications they are used in the charts and area summaries. Where such figures were not given in original publications they have been estimated, where reasonably possible, from data available from other sources such as Montana Highway Department test hole logs, and reports on adjacent areas. The letter "b" in parentheses after a number in the individual area summaries indicates that the number was estimated or determined by the compiler and not by the authors of the source publications.

The permeable thickness is the average thickness of permeable materials penetrated by wells or test holes in the area of the investigation.

The saturated thickness is the thickness of permeable materials that is estimated to contain free water. This thickness changes during the year with the water table rising in response to recharge and falling during the periods when discharge exceeds recharge. Water-table fluctuation ranges from about 1 foot in areas that receive little recharge, to 10 feet or more in areas that receive more than normal recharge, such as those that are extensively irrigated.

The specific yield is the fraction of the saturated pore space from which the water can drain by gravity, thus becoming available to wells.

Available storage is the amount of water in an aquifer that can be pumped from wells. In some of the large alluvial areas, such as the Missoula Basin, available storage estimates are determined by the amount of water recoverable from the upper part of the saturated zone. For instance, in the Missoula Basin it is estimated that total storage amounts to 30 million acre-feet of water, and that 8 million acre-feet is available to wells. Because of economic limitations on well depths and pumping lifts the figure of 1¾ million acre-feet recoverable from the upper 200 feet of the aquifer is given, and under present economic conditions this is probably a more realistic figure to use in planning further development.

Perennial recharge is the average amount of water, in excess of evapotranspiration and outflow, which is supplied to the groundwater reservoir each year. This is the quantity that can be used without depleting available storage. Due to the vagaries of precipitation, there will be some seasons when the actual amount of recharge will be considerably more or less. For instance, in the Gallatin Valley, average perennial recharge less evapotranspiration loss is estimated at 240,000 acre-feet, but records through a span of 19 years show this figure to have been as low as 120,000 acre-feet and as high as 320,000 acre-feet.

Pump test data are available for only a few areas. This information includes specific capacity, which is the quantity of water produced by a well in gallons per minute per foot of drawdown.

Transmissibility is also determined by pump testing and is a measure of the capacity of the aquifer to transmit water. Transmissibility is the number of gallons of water per day that will flow across each mile strip of the aquifer under a hydraulic gradient of one foot per mile.

All the unconsolidated aquifers are referred to the index map and to the Montana drainage basin map in the area summaries as well as on the charts.

Figure 2 shows the location of the unconsoli-

dated aquifer summaries with respect to drainage basins. The aquifer summaries and the charts are arranged in the text in the same order in which the corresponding drainage basin is listed on the key to Figure 2. For this reason a reference is provided below so that the summaries can be located in the text using the drainage basin code number. A reference is also provided to locate the summaries in the text using the index map number of the report from which the summary was prepared. (See index map, Figure 1.)

Number of report on index map	Summary on page
1	50, 52
2	86
3	92
4	10, 12
5	42
6	58, 80
7	60
8	64
10	56
12	94, 106
13	62
17	28
18	20
20	96, 98, 100, 102, 104
21	44
22	62, 64
23	20
24	42
25	90
26	66
27	10, 12
28	14
29	64
30	90
31	40
32	76
33	16
34	88
35	9, 72, 82
36	68, 70
37	88
38	56
39	48, 54
40	106
42	106
44	46
45	18
46	56
47	56
48	48, 54
49	96, 98, 100, 102, 104
52	78
53	96, 98, 100, 102, 104
54	36
55	22, 24, 26, 28, 34, 38
56	88
58	84
59	80
60	24

Three summaries prepared for areas not listed on index map are:

Elk Park Valley	Page 30
Boulder Valley	Page 32
Clarks Fork and Rock Creek Valleys	Page 74

INDEX MAP SHOWING LOCATION OF GROUNDWATER AND RELATED INVESTIGATIONS IN MONTANA

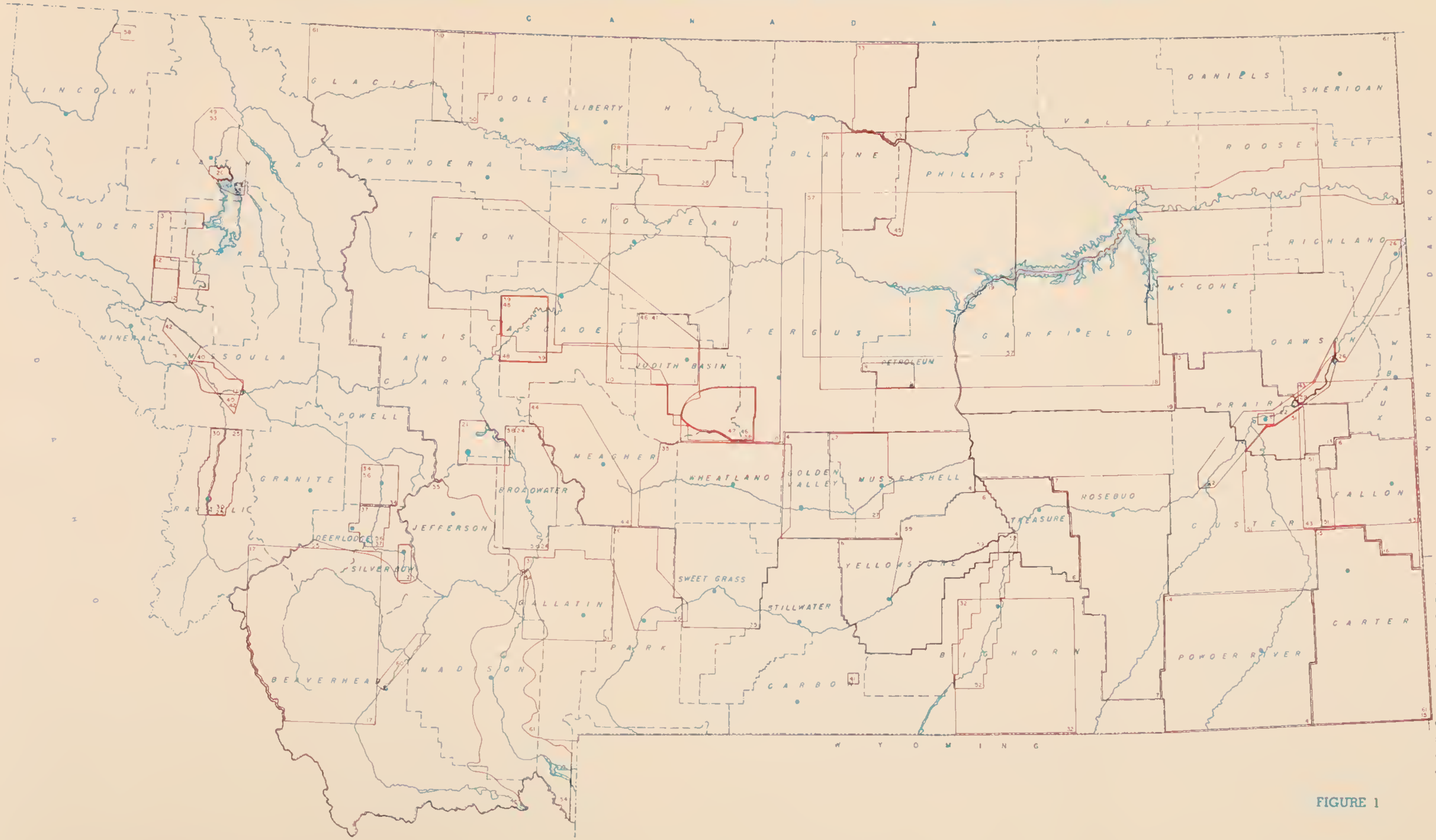


FIGURE 1

dated
basin:
arran
corres
to Fig
below

KEY TO RIVER BASIN MAP (Figure 2)

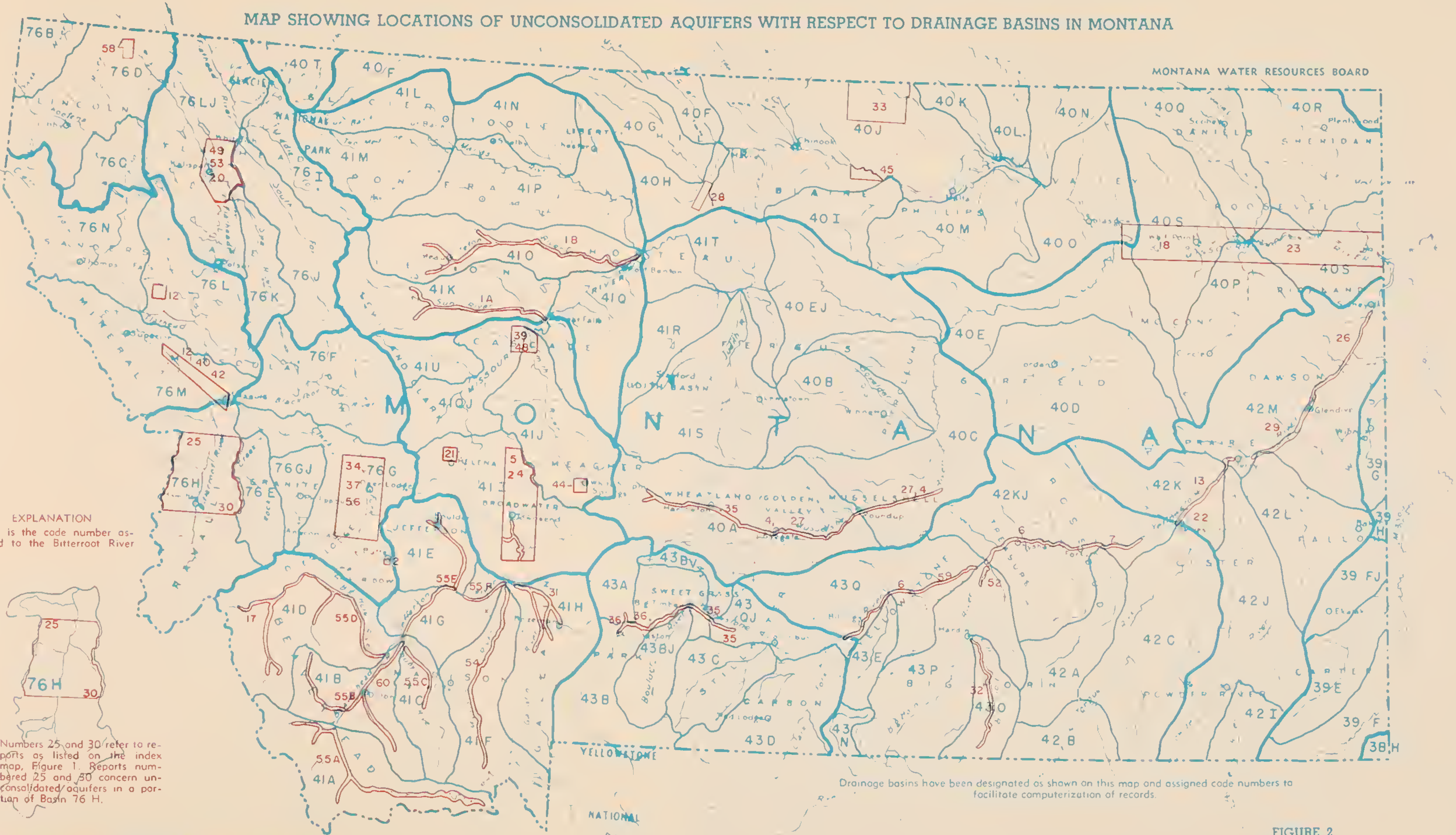
MONTANA DRAINAGE BASINS

Code No.	
38H	BELLE FOURCHE RIVER ABOVE CHEYENNE RIVER
39E	BOX ELDER CREEK
39F	LITTLE MISSOURI RIVER ABOVE LITTLE BEAVER CREEK
39FJ	LITTLE BEAVER CREEK
39G	BEAVER CREEK
39H	LITTLE MISSOURI BELOW LITTLE BEAVER CREEK
40A	MUSSELSHELL RIVER ABOVE ROUNDUP
40B	FLATWILLOW CREEK INCLUDING BOX ELDER CREEK
40C	MUSSELSHELL RIVER BELOW ROUNDUP
40D	DRY CREEK
40E	MISSOURI RIVER BETWEEN MUSSELSHELL RIVER AND FORT PECK DAM
40EJ	MISSOURI RIVER BETWEEN BULLWHACKER CREEK AND MUSSELSHELL RIVER
40F	MILK RIVER ABOVE FRESNO RESERVOIR
40G	SAGE CREEK
40H	BIG SANDY CREEK
40 I	PEOPLES CREEK
40J	MILK RIVER BETWEEN FRESNO RESERVOIR AND WHITEWATER CREEK
40K	WHITEWATER CREEK
40L	FRENCHMAN RIVER
40M	BEAVER CREEK
40N	ROCK CREEK
40O	MILK RIVER BELOW WHITEWATER CREEK INCLUDING PORCUPINE CREEK
40P	REDWATER RIVER
40Q	POPLAR RIVER
40R	BIG MUDDY CREEK
40S	MISSOURI RIVER BELOW FORT PECK DAM
40T	HUDSON BAY DRAINAGE (PART 5)
41A	RED ROCK RIVER
41B	BEAVERHEAD RIVER
41C	RUBY RIVER
41D	BIG HOLE RIVER
41E	BOULDER RIVER
41F	MADISON RIVER
41G	JEFFERSON RIVER
41H	GALLATIN RIVER
41 I	MISSOURI RIVER ABOVE HOLTER DAM
41J	SMITH RIVER
41K	SUN RIVER
41L	CUT BANK CREEK
41M	TWO MEDICINE CREEK
41N	WILLOW CREEK
41 O	TETON RIVER
41P	MARIAS RIVER
41QJ	MISSOURI RIVER FROM HOLTER DAM TO THE SUN RIVER

Code No.	
41Q	MISSOURI RIVER FROM SUN RIVER TO MARIAS RIVER
41R	ARROW CREEK
41S	JUDITH RIVER
41T	MISSOURI RIVER FROM MARIAS RIVER TO AND INCLUDING BULLWHACKER CREEK
41U	DEARBORN RIVER
42A	ROSEBUD CREEK
42B	TONGUE RIVER ABOVE AND INCLUDING HANGING WOMAN CREEK
42C	TONGUE RIVER BELOW HANGING WOMAN CREEK
42 I	LITTLE POWDER RIVER
42J	POWDER RIVER BELOW CLEAR CREEK
42KJ	YELLOWSTONE RIVER BETWEEN BIGHORN RIVER AND TONGUE RIVER
42K	YELLOWSTONE RIVER BETWEEN TONGUE AND POWDER RIVER
42L	O'FALLON CREEK
42M	YELLOWSTONE RIVER BELOW POWDER RIVER
43A	SHIELDS RIVER
43B	YELLOWSTONE RIVER ABOVE AND INCLUDING BRIDGER CREEK
43BJ	BOULDER RIVER
43BV	SWEET GRASS CREEK
43C	STILLWATER RIVER
43D	CLARKS FORK YELLOWSTONE RIVER
43E	PRYOR CREEK
43N	SHOSHONE RIVER
43 O	LITTLE BIGHORN RIVER
43P	BIGHORN RIVER BELOW GREYBULL RIVER
43Q	YELLOWSTONE RIVER BETWEEN CLARKS FORK YELLOWSTONE AND BIGHORN RIVERS
43QJ	YELLOWSTONE RIVER FROM BRIDGER CREEK TO THE CLARKS FORK YELLOWSTONE
76B	YAAK RIVER
76C	FISHER RIVER
76D	KOOTENAI RIVER
76E	ROCK CREEK
76F	BLACKFOOT RIVER
76G	CLARKS FORK ABOVE BLACKFOOT RIVER
76GJ	FLINT CREEK
76H	BITTERROOT RIVER
76 I	MIDDLE FORK FLATHEAD RIVER
76J	SOUTH FORK FLATHEAD RIVER
76K	SWAN RIVER
76LJ	FLATHEAD RIVER TO AND INCLUDING FLATHEAD LAKE
76L	FLATHEAD RIVER BELOW FLATHEAD LAKE
76M	CLARK FORK BETWEEN BLACKFOOT RIVER AND FLATHEAD RIVER
76N	CLARK FORK BELOW FLATHEAD RIVER

MAP SHOWING LOCATIONS OF UNCONSOLIDATED AQUIFERS WITH RESPECT TO DRAINAGE BASINS IN MONTANA

MONTANA WATER RESOURCES BOARD



EXPLANATION

76 H is the code number assigned to the Bitterroot River basin.

Numbers 25 and 30 refer to reports as listed on the index map, Figure 1. Reports numbered 25 and 30 concern unconsolidated aquifers in a portion of Basin 76 H.

Drainage basins have been designated as shown on this map and assigned code numbers to facilitate computerization of records.

FIGURE 2

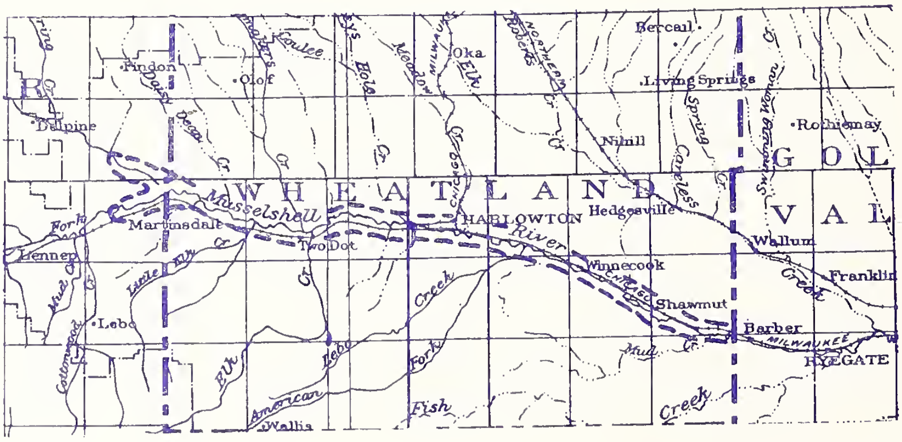
MONTANA
MAJOR AND SUBMAJOR DRAINAGE BASINS
JANUARY 1, 1969

INDEX MAP NUMBER 35

Wheatland, eastern Meagher Counties
Drainage basin 40A

Groundwater in storage, available to wells	40,000(b) acre-feet
Perennial recharge	6,000(b) acre-feet

Quality - Domestic - Satisfactory



Portion of the Report Area.

The outline shows the general location of the aquifer in Musselshell River Valley unconsolidated deposits.

Area of aquifer	27,000(b) acres
Specific yield to aquifer	.1(b)
Average aquifer thickness (saturated thickness)	15(b) feet
Average thickness permeable alluvium	25(b) feet
Transmissibility	gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER 35

Wheatland, eastern Meagher Counties
Drainage basin 40A

Precipitation	12 inches annual average
Well depths	18 - 140 feet
Water table	4 - 120 feet
Well yields	Small to large
Specific capacities	gpm/ft.
Number of wells	30+
Temperature of well water	°F
Well uses	Chiefly stock and domestic

Remarks: Computations based on Musselshell River alluvium.

References:

Reconnaissance groundwater studies, Wheatland, eastern Meagher, and northern Sweet Grass Counties, Montana: MBMG Spec. Pub. 24, 1962.

INDEX MAP NUMBERS 4, 27

Golden Valley and Musselshell Counties
Drainage basin 40A

Groundwater in storage, available to wells .... 27,000(b) acre-feet
Perennial recharge .... 4,000(b) acre-feet
Quality—Domestic 1-5, Irrigation 1-5

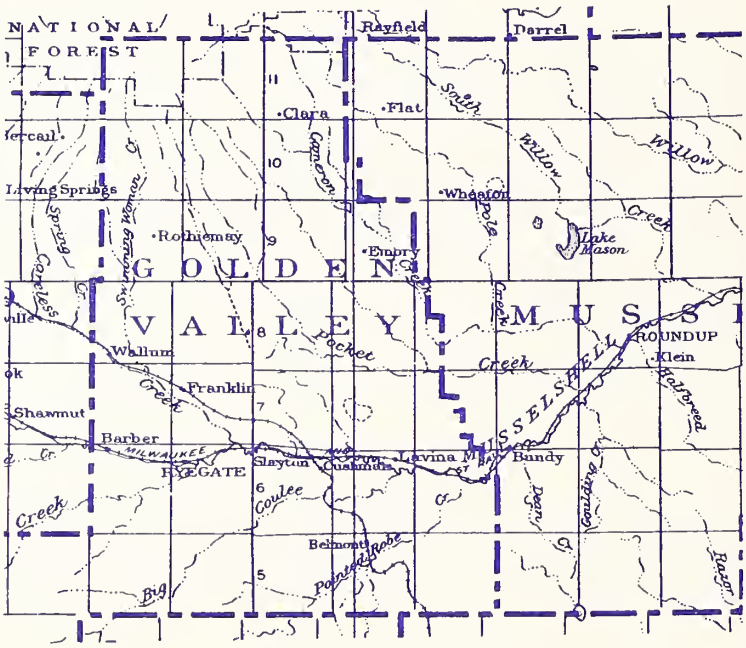


FIG. 4

Report Area.

The aquifer is in alluvium bordering the Musselshell River from the western boundary of Golden Valley County to Roundup.

Area of aquifer .... 12,000(b) acres
Specific yield of aquifer .... .15(b)
Average aquifer thickness (saturated thickness) .... 15(b) feet
Average thickness permeable alluvium .... 30(b) feet
Transmissibility ....gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBERS 4, 27

Golden Valley and Musselshell Counties
Drainage Basin 40A

Precipitation	12 inches annual average
Well depths	9 - 60 feet
Water table	6 - 22 feet
Water yields to 500 gpm	most wells 10 - 20 gpm
Specific capacities	gpm/ft.
Number of wells	38+
Temperature of well water	49° F
Well uses	Chiefly stock and domestic

Remarks: The aquifer considered in this summary is limited to alluvium along the Musselshell River.

References:

Groundwater in Musselshell and Golden Valley Counties, Montana: USGS Water-Supply Paper 518, 1924.

Preliminary report on the geology and groundwater resources of parts of Musselshell and Golden Valley Counties, Montana: MBMG Inf. Circ. 15, 1956.

Water Resources Survey, Golden Valley County, 1949, and Musselshell County, 1949: State Engineer's Office, Helena.

Unpublished well records in files of USGS, Billings.

INDEX MAP NUMBERS 4, 27

Musselshell County
Drainage basin 40C

Groundwater in storage, available to wells	50,000(b) acre-feet
Perennial recharge	8,000(b) acre-feet

Quality—Domestic 1-5, Irrigation 1-5

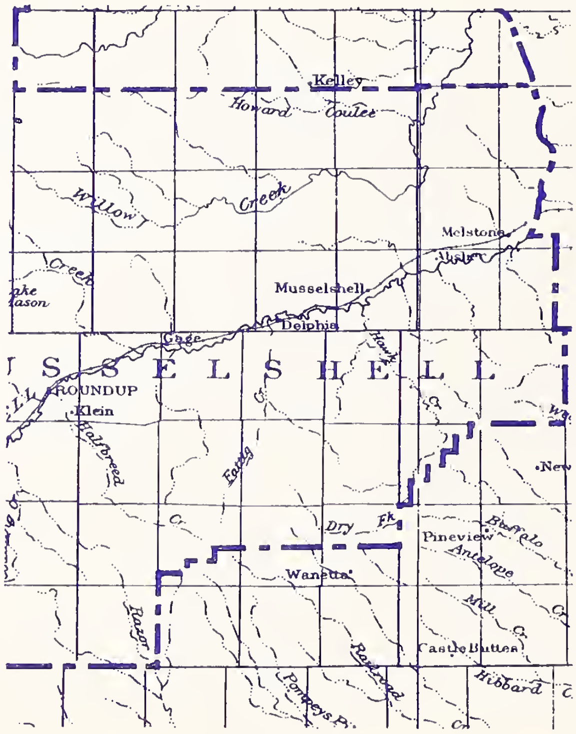


FIG. 5

Area Summarized.

The aquifer is in Musselshell Valley alluvium bordering the river from Roundup downstream to the Musselshell County north line.

Area of aquifer	22,000(b) acres
Specific yield of aquifer	.15(b)
Average aquifer thickness (saturated thickness)	15(b) feet
Average thickness permeable alluvium	30(b) feet
Transmissibility	gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBERS 4, 27

Musselshell County
Drainage basin 40C

Precipitation	12 inches annual average
Well depths	10 - 39 feet
Water table	6 - 27 feet
Well yields to 500 gpm	most wells 5 - 20 gpm
Specific capacities	gpm/ft.
Number of wells	52+
Temperature of well water	49° F
Well uses	Chiefly stock and domestic

Remarks:

References:

Groundwater in Musselshell and Golden Valley Counties, Montana: USGS Water-Supply Paper 518, 1924.

Preliminary report on the geology and groundwater resources of parts of Musselshell and Golden Valley Counties, Montana: MBMG Inf. Circ. 15, 1956.

Water Resources Survey, Golden Valley County, 1949, and Musselshell County, 1949: State Engineer's Office, Helena.

Unpublished well records in files of USGS, Billings.

INDEX MAP NUMBER 28

Lower Marias irrigation project
Drainage basin 40H

Groundwater in storage, available to wells .... 396,000(b) acre-feet
Perennial recharge .... 20,000(b) acre-feet
Quality—Domestic 1-5, Irrigation 1-5, mostly 5

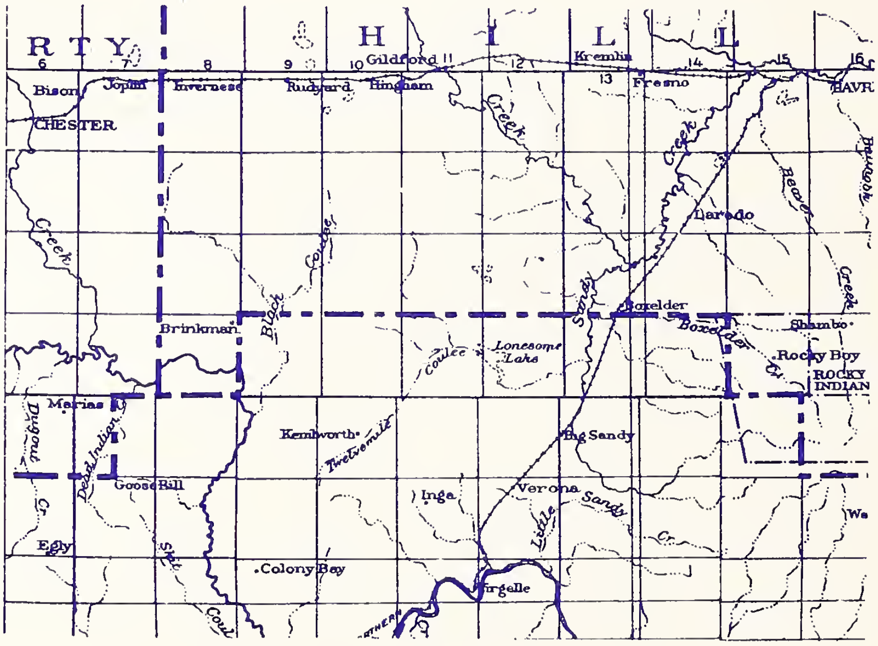


FIG. 6

Report Area.

This summary is concerned with the alluvial aquifer in the Big Sandy-Laredo vicinity.

Area of aquifer .... 44,000(b) acres
Specific yield of aquifer .... .15(b)
Average aquifer thickness (saturated thickness) .... 60(b) feet
Average thickness permeable alluvium ....100 feet ±
Transmissibility .... gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER 28

Lower Marias irrigation project
Drainage basin 40H

Precipitation	12 inches annual average
Well depths	11 - 400 feet
Water table	3 - 154 feet
Well yields, 15 - 50 gpm	potential in excess of 250 gpm
Specific capacities (one only)	25 gpm/ft.
Number of wells	207±
Temperature of well water	°F
Well uses	Chiefly stock and domestic

Remarks: Storage and recharge figures have been computed only for the alluvial area around Big Sandy and northeast toward Laredo.

Most of this area is within the limits of the buried preglacial Missouri River Channel.

References:

Geology and groundwater resources of the lower Marias irrigation project Montana: USGS Water-Supply Paper 1460-B, 1957.

Water Resources Survey, Chouteau County, Montana: State Engineer's Office, Helena, 1964.

Water Resources Survey, Hill County, Montana: State Water Conservation Board, Helena, 1967.

INDEX MAP NUMBER 33

Northern Blaine County
Drainage basin 40J

Groundwater in storage, available to wells	300,000 acre-feet
Perennial recharge	5,000 acre-feet

Quality—Domestic 1-3, Irrigation 1

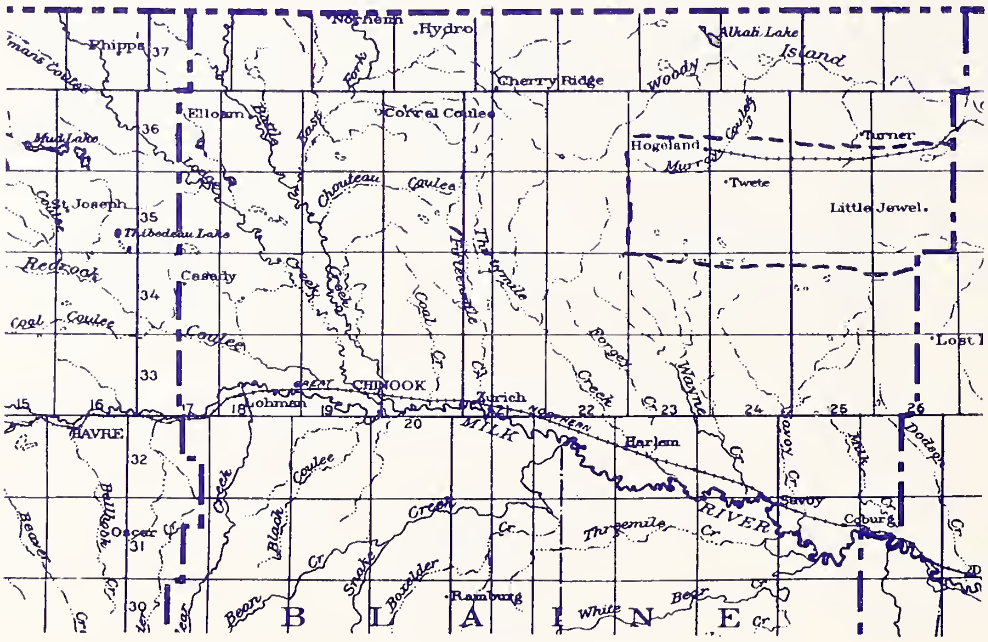


FIG. 7

Outline of general area in which wells produce water from sands and gravels in the Flaxville Formation.

Area of aquifer	100,000 acres
Specific yield of aquifer	.2
Average aquifer thickness (saturated thickness)	15 feet
Average thickness permeable alluvium	75 feet
Transmissibility	gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER 33

Northern Blaine County
Drainage basin 40J

Springs and evapotranspiration, quantities unknown.

Precipitation	12 inches annual average Infiltration rate 5%
Well depths	39 - 49 feet
Water table	30 feet (one well only)
Well yields	Up to 1200 gpm
Specific capacities	gpm/ft.
Number of wells	20+
Temperature of well water	46° - 49° F

Well uses—Irrigation, stock and domestic. Light irrigation available for 7000 acres.

Remarks:

Large capacity wells should be spaced at least one mile apart.

Small yields from glacial till, glacial outwash; good water, but few wells. Milk River alluvium, moderate yields of poor water. Tributaries, moderate yields, fair quality.

References:

Geology and groundwater resources of northern Blaine County, Montana: MBMG Bull. 19, 1960.

*Water Resources Survey, Blaine County, Montana: State Water Conservation Board, 1967.

*In the Blaine County Water Resources Survey, the area of the Flaxville aquifer is given as 150,000 acres, porosity 30%, ground water in storage 900,000 ac-ft, effective aquifer thickness 15 feet-25 feet, and recharge 5000-7000 ac-ft. annually.

INDEX MAP NUMBER 45

Fort Belknap Indian Reservation

Drainage basin 40J

Groundwater in storage, available to wells .... 57,000(b) acre-feet

Perennial recharge .... 11,000(b) acre-feet

Quality—Domestic 3-5, Irrigation 5

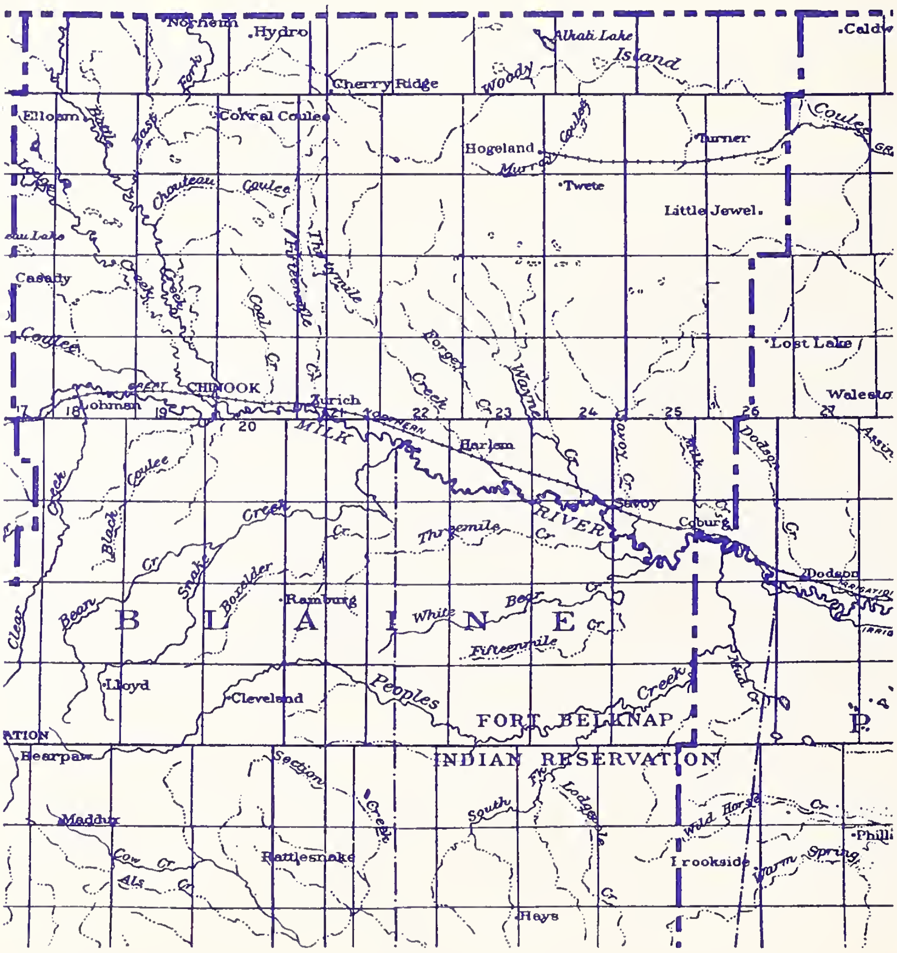


FIG. 8

Portion of the Report Area.

The aquifer is in alluvium bordering the Milk River.

Area of aquifer .... 38,000(b) acres

Specific yield of aquifer .... .15(b)

Average aquifer thickness (saturated thickness) .... 10(b) feet

Average thickness permeable alluvium .... 30(b) feet

Transmissibility (in pre-glacial channel gravels) ....66,000 gpd/ft.

Transmissibility is very low in the sandy beds.

SPECIFIC INFORMATION
INDEX MAP NUMBER 45

Fort Belknap Indian Reservation
Drainage basin 40J

Precipitation	12 inches annual average
Well depths	7 - 83 feet
Water table	3 - 16 feet
Well yields	Small to large
Specific capacities	gpm/ft.
Number of wells	37+
Temperature of well water	°F
Well uses	Chiefly stock and domestic

Remarks: Area of aquifer includes all of the Milk River alluvium. Alluvium on north side of river is in the area of MBMG Bull. 19.

Good water in underflow of coulees draining Little Rocky Mountains, especially near Hays in T. 26 N., R. 24 E. Loss of water for the entire report area is 627,000 ac-ft/yr. due to evapotranspiration and 7,000 ac-ft/yr. ground-water discharge. The figure of 11,000 acre-feet for perennial recharge includes recharge from irrigation which was not evaluated in the original report.

References:

Geology and hydrology of the Fort Belknap Indian Reservation, Montana: USGS Water-Supply Paper 1576-F, 1965.

INDEX MAP NUMBERS 18, 23

Missouri River Valley (northeastern Montana)
Drainage basin 40S

Groundwater in storage, available to wells	345,000(b) acre-feet
Perennial recharge	70,000(b) acre-feet

Quality—Domestic 1-5, Irrigation mostly 5

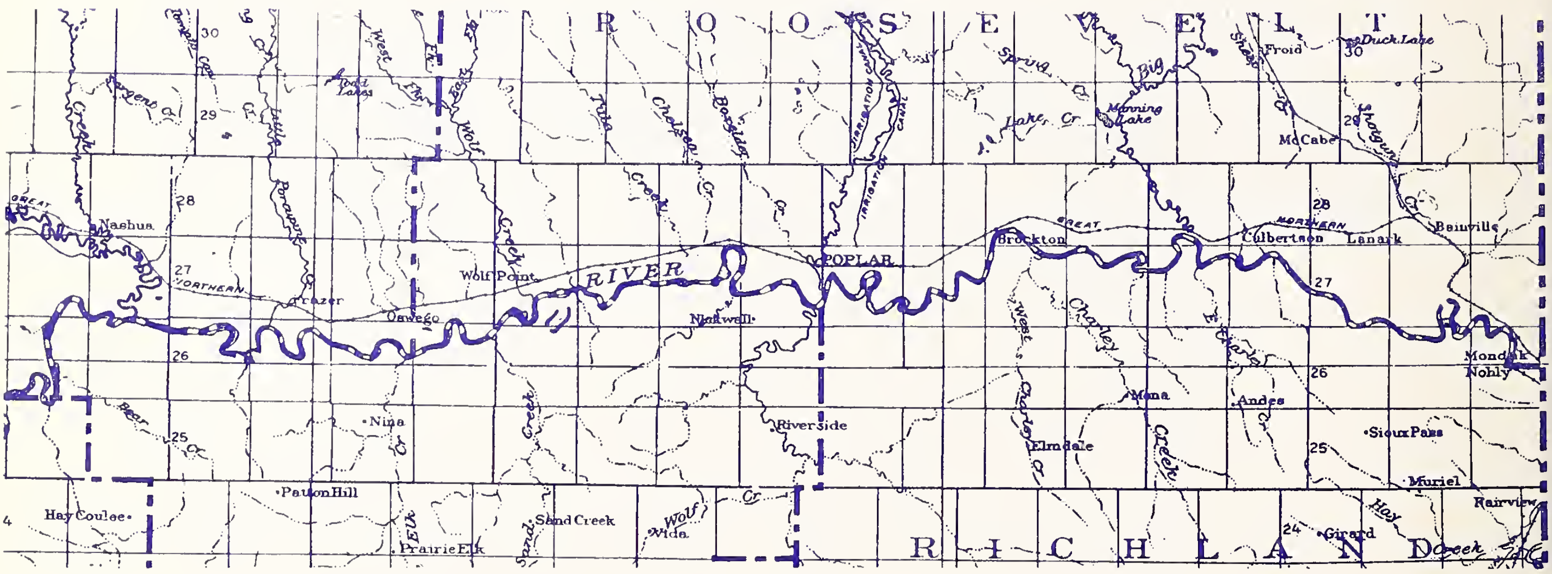


FIG. 9

Area Summarized.

The aquifer is in alluvium bordering the Missouri River.

Area of aquifer	157,000 acres
Specific yield of aquifer	.15(b)
Average aquifer thickness (saturated thickness)	15(b) feet
Average thickness permeable alluvium	65(b) feet
Transmissibility	gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBERS 18, 23

Missouri River Valley (northeastern Montana)
Drainage basin 40S

Precipitation	12 inches annual average
Well depths	15 - 210 feet
Water table	5 - 70 feet
Well yields	18 - 650 gpm
Specific capacities	20 - 91 gpm/ft.
Number of wells	200+
Temperature of well water	°F
Well uses	Chiefly stock and domestic

Remarks: Irrigation and drainage may improve water quality in alluvium.

References:

Geology and artesian water resources along Missouri and Milk Rivers in northeastern Montana: MBMG Mem. 11, 1934.

Geology and groundwater resources of the Missouri River Valley in northeastern Montana: USGS Water-Supply Paper 1263, 1955.

INDEX MAP NUMBER 55

Red Rock River Valley
Drainage basin 41A

Groundwater in storage, available to wells .... 200,000 acre-feet
Perennial recharge .... 40,000 acre-feet
Quality—Domestic 1, Irrigation 1

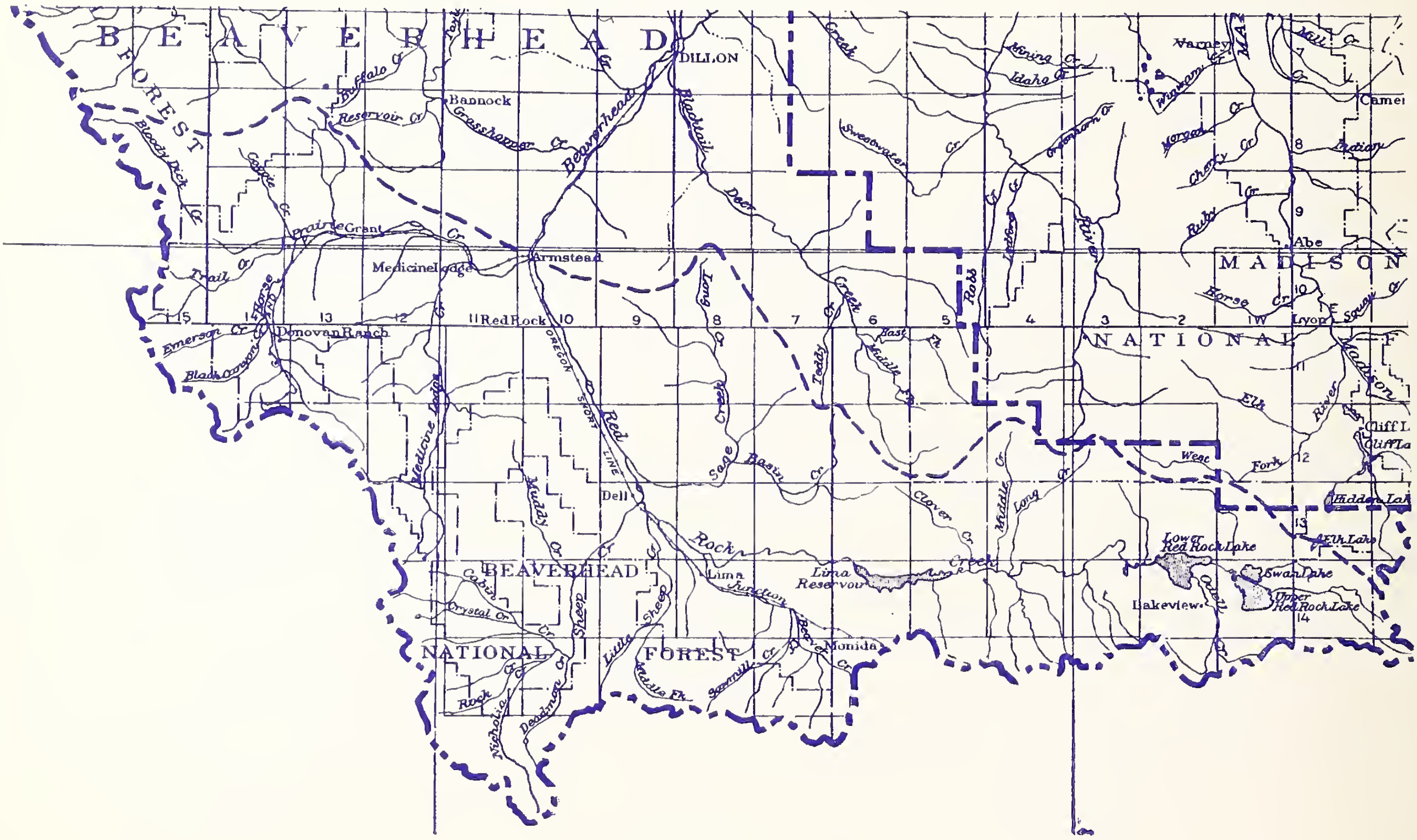


FIG. 10

Outline of Red Rock River Basin.

The aquifers are in alluvial deposits along Red Rock River and major tributaries.

Area of aquifer .... 200,000 acres
Specific yield of aquifer .... .10(b)
Average aquifer thickness (saturated thickness) .... 10(b) feet
Average thickness permeable alluvium .... 30(b) feet
Transmissibility .... gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER 55

Red Rock River Valley
Drainage basin 41A

Precipitation .... 14 inches annual average
Well depths .... 17 - 499 feet
Water table .... 3 - 235 feet
Well yields .... 4 - 1200 gpm
Specific capacities .... .2 - 3.0 gpm/ft.
Number of wells ....
Temperature of well water .... °F
Well uses .... Stock and domestic, some irrigation
Remarks:

References:

Water power and irrigation in the Jefferson River Basin, Montana: USGS Water-Supply Paper 580-B, 1926.
Well data from groundwater files: Montana Water Resources Board.

INDEX MAP NUMBERS 55, 60

Beaverhead River Valley
Drainage basin 41B

Groundwater in storage, available to wells .... 234,000(b) acre-feet
Perennial recharge .... 40,000(b) acre-feet
Quality—Domestic 1, Irrigation 1

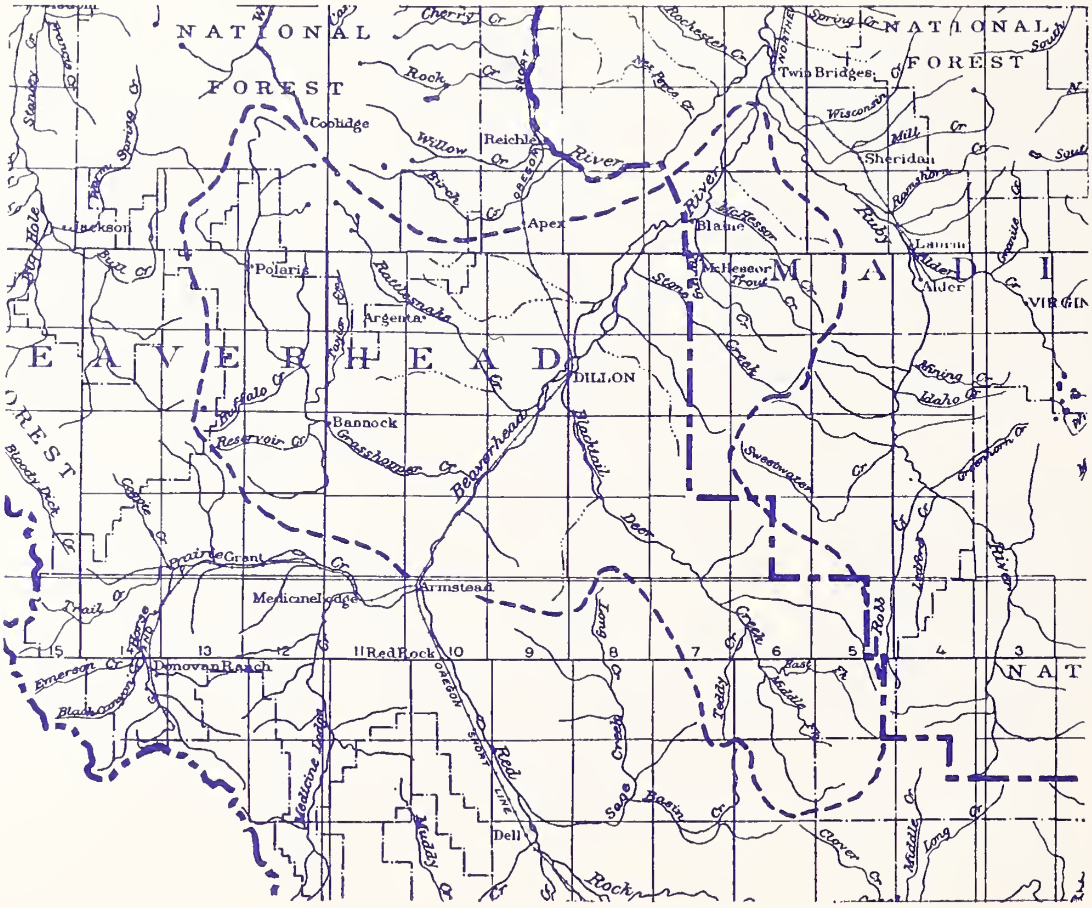


FIG. 11

Outline of Beaverhead Drainage Basin.

Aquifers are in alluvium along Beaverhead River and major tributaries.

Area of aquifer .... 78,000 acres
Specific yield of aquifer .... .15(b)
Average aquifer thickness (saturated thickness) .... 20(b) feet
Average thickness permeable alluvium ....100(b) feet
Transmissibility ....to 660,000 gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBERS 55, 60

Beaverhead River Valley
Drainage basin 41B

Precipitation	12 inches annual average
Well depths	15 - 160 feet
Water table	3 - 124 feet
Well yields	5 - 1800 gpm, most 5 - 20 gpm
Specific capacities	Up to 300 gpm/ft. Most in the range of .5 to 30 gpm/ft.
Number of wells	
Temperature of well water	°F
Well uses	Stock, domestic, some irrigation

Remarks: Water table fluctuation 5 - 15 feet.

References:

Water power and irrigation in the Jefferson River Basin, Montana: USGS Water-Supply Paper 560-B, 1926.

Hydrogeology of the East Banch irrigation unit, Madison and Beaverhead Counties, Montana: Mont. Geol. Society Guidebook, 1967.

Well data from groundwater files: Montana Water Resources Board.

INDEX MAP NUMBER 55

Ruby River Valley
Drainage basin 41C

Groundwater in storage, available to wells .... 35,000(b) acre-feet

Perennial recharge .... 6,000(b) acre-feet

Quality—Domestic 1, Irrigation 1

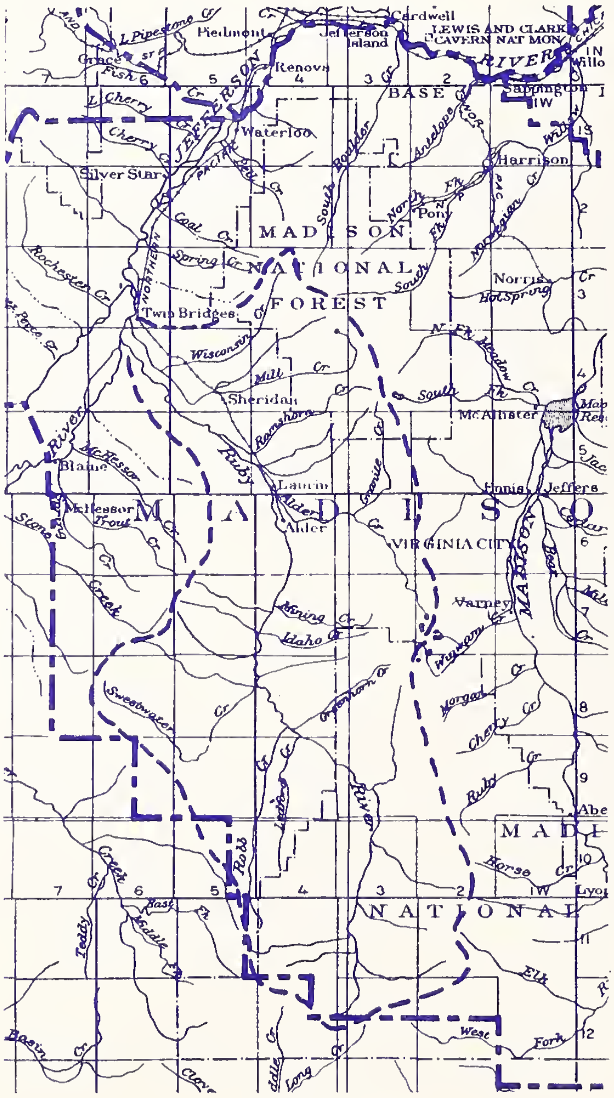


FIG. 12

Outline of Ruby River Valley.

The aquifer is in alluvium along the Ruby River.

Area of aquifer .... 34,500 acres

Specific yield of aquifer .... .10(b)

Average aquifer thickness (saturated thickness) .... 10(b) feet

Average thickness permeable alluvium .... 25(b) feet

Transmissibility .... gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER 55

Ruby River Valley
Drainage basin 41C

Precipitation	12 inches annual average
Well depths	33 - 155 feet
Water table	4 - 110 feet
Well yields	10 - 30 gpm
Specific capacities	.6 to 3 gpm/ft.
Number of wells	
Temperature of well water	°F
Well uses	Stock and domestic

Remarks:

References:

Water power and irrigation in the Jefferson River Basin, Montana: USGS Water-Supply Paper 560-B, 1926.
Well data from groundwater files: Montana Water Resources Board.

INDEX MAP NUMBERS 17, 55

Big Hole Basin
Drainage basin 41D

Groundwater in storage, available to wells .... 1,100,000(b) acre-feet
Perennial recharge .... 180,000(b) acre-feet
Quality—Domestic and irrigation—1

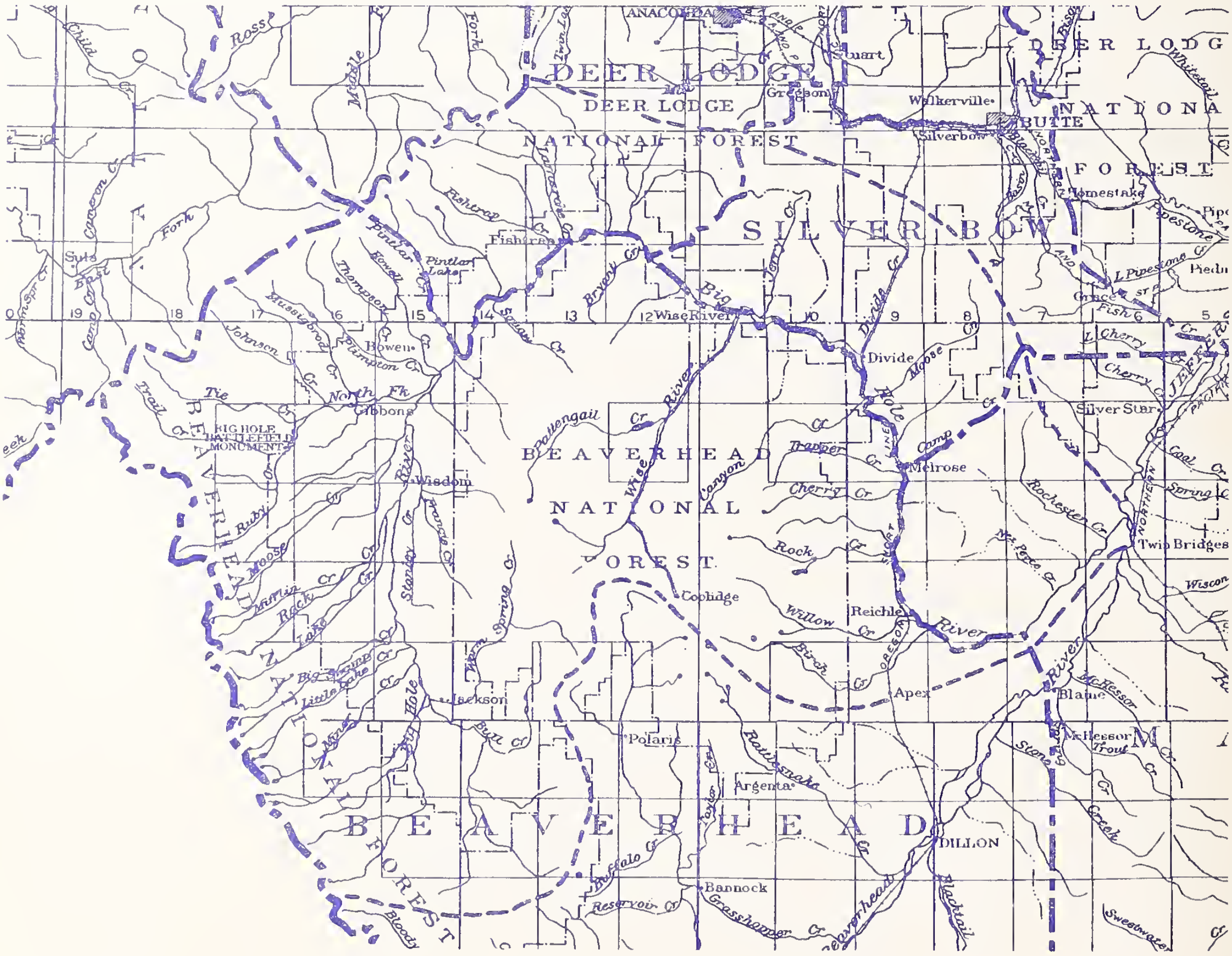


FIG. 13

Outline of Big Hole Basin.

Area of aquifer .... 248,000 acres
Specific yield of aquifer .... .15(b)
Average aquifer thickness (saturated thickness) .... 30(b) feet
Average thickness permeable alluvium ....160(b) feet
Transmissibility .... gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBERS 17, 55

Big Hole Basin
Drainage basin 41D

Precipitation	12 inches annual average
Well depths	20 - 320 feet
Water table	6 - 77 feet
Well yields 8 - 34 gpm	potential 250 - 1000 gpm
Specific capacities	8 - 34 gpm/ft.
Number of wells	
Temperature of well water	°F
Well uses	Chiefly stock and domestic

Remarks:

References:

Physiography and groundwater supply in the Big Hole Basin, Montana: MBMG Mem. 12, 1934.

Montana Highway Department logs of test holes.

Water power and irrigation in the Jefferson River Basin, Montana: USGS Water-Supply Paper 580-B, 1926.

Elk Park Valley

Drainage basin 41E

Groundwater in storage, available to wells .... 40,000(b) acre-feet

Perennial recharge .... 6,000(b) acre-feet

Quality (Estimate)—Domestic 1, Irrigation 1

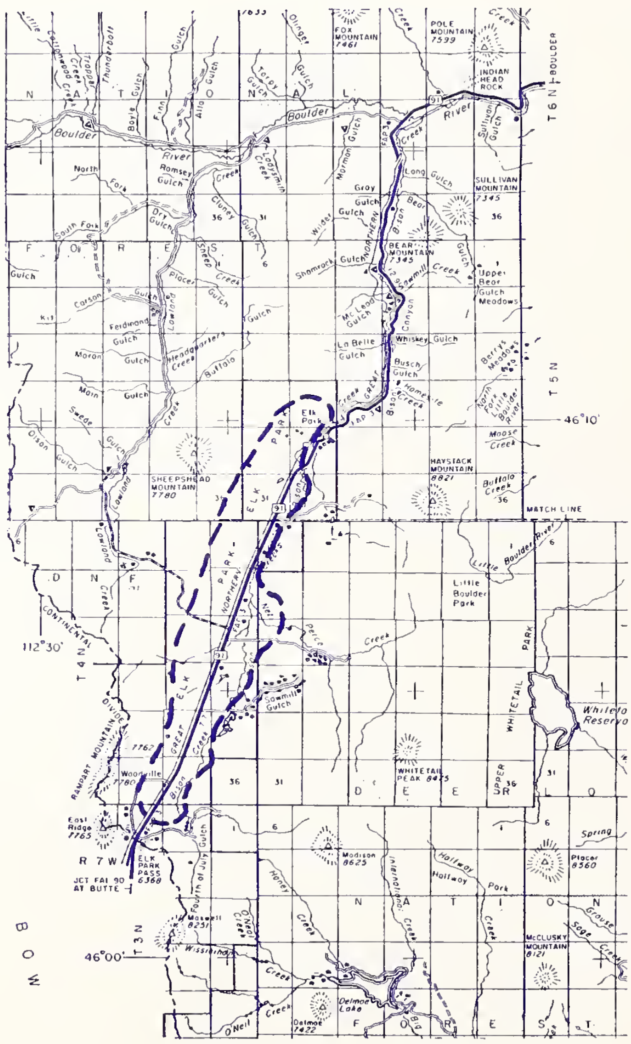


FIG. 14

Elk Park basin alluvial area enclosed by dashed line.

Area of aquifer .... 9,000(b) acres

Specific yield of aquifer .... .15(b)

Average aquifer thickness (saturated thickness) .... 30(b) feet

Average thickness permeable alluvium .... 45(b) feet

Transmissibility .... gpd/ft.

Elk Park Valley
Drainage basin 41E

Losses	
Precipitation	14 inches annual average
Well depths (test holes)	17 - 66 feet
Water table (test holes)	2 - 18 feet
Well yields	
Specific capacities	
Number of wells	Unknown
Temperature of well water	
Well uses	Stock and domestic

Remarks: Recharge is in excess of reservoir capacity as shown by marsh areas.

References:

Montana Highway Department test hole logs. Elk Park, Montana, 15′ topographic map, USGS, 1954.

Boulder Valley

Drainage basin 41E

Groundwater in storage, available to wells .... 50,000(b) acre-feet
Perennial recharge .... 8,000(b) acre-feet
Quality—Domestic 1, Irrigation 1

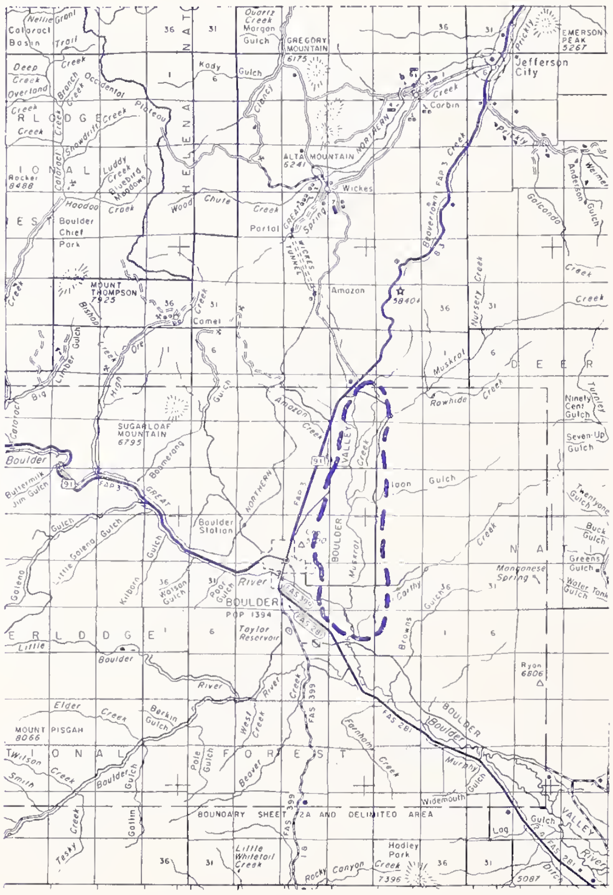


FIG. 15

Boulder Valley alluvial area enclosed by dashed line.

Area of aquifer .... 3200 acres
Specific yield of aquifer .... .20
Average aquifer thickness (saturated thickness) .... 80 feet
Average thickness permeable alluvium ....100 feet
Transmissibility .... 133,000 - 155,000 gpd/ft.

Losses ....

Precipitation .... 12 inches annual average

Well depths .... 72 - 90 feet

Water table .... 20 feet (average)

Well yields 80 - 240 gpm ....potential 1700 - 3500 gpm

Specific capacities .... 12 - 60 gpm/ft.

Number of wells .... 5+

Temperature of well water ....

Well uses....Chiefly stock and domestic, 1 municipal, and 1 institutional well

Remarks:

References:

Letter dated Dec. 19, 1968, to the acting chief engineer, Montana Water Resources Board, from M. K. Botz, Montana Bureau of Mines and Geology.

INDEX MAP NUMBER 55

Boulder River Valley

Drainage basin 41E

Groundwater in storage, available to wells	16,000(b) acre-feet
Perennial recharge	3,000(b) acre-feet
Quality—Domestic 1, Irrigation 1	

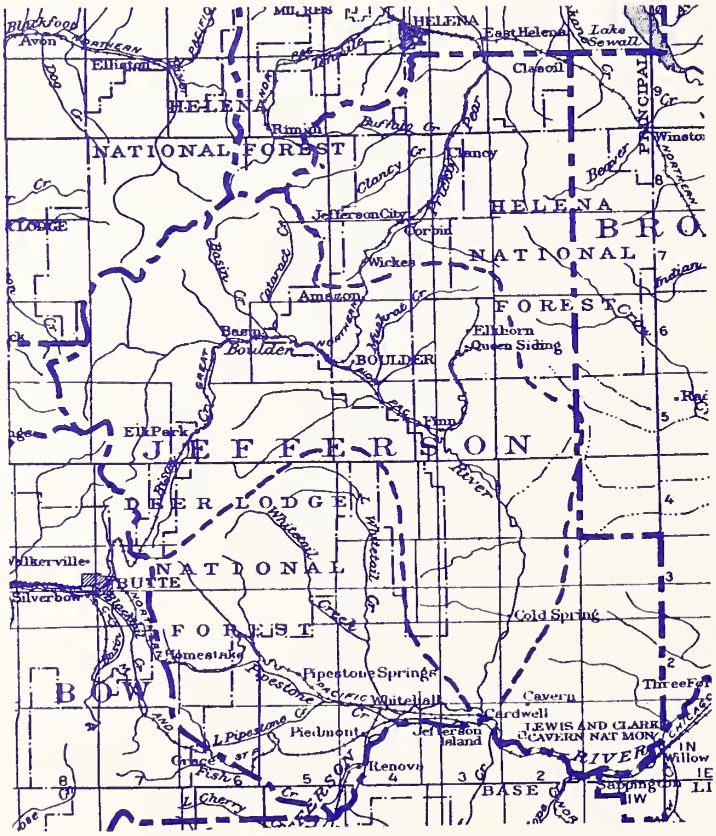


FIG. 16

Outline of Boulder River Basin.

The aquifer is in alluvium along the Boulder River, from the Boulder vicinity downstream to Cardwell.

Area of aquifer	16,000 acres
Specific yield of aquifer	.10(b)
Average aquifer thickness (saturated thickness)	10(b) feet
Average thickness permeable alluvium	20(b) feet
Transmissibility	gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER 55

Boulder River Valley
Drainage basin 41E

Precipitation	10 inches annual average
Well depths	12 - 260 feet
Water table	6 - 180 feet
Well yields, potential at least 250 gpm	most 8 - 50 gpm
Specific capacities	12 - 60 gpm/ft.
Number of wells	
Temperature of well water	°F

Well uses—Chiefly stock and domestic, one municipal and one institutional well.

Remarks: Most of the water in available storage is in the alluvial areas of Boulder Valley and Elk Park.

References:

Water power and irrigation in the Jefferson River Basin, Montana: USGS Water-Supply Paper 560-B, 1926.

Montana Highway Department test hole logs.

Letter, December 19, 1968, from M. K. Botz, Montana Bureau of Mines and Geology, to Montana Water Resources Board.

INDEX MAP NUMBER 54

Madison River Valley
Drainage basin 41F

Groundwater in storage, available to wells .... 260,000(b) acre-feet
Perennial recharge .... 40,000(b) acre-feet
Quality—Domestic 1, Irrigation 1

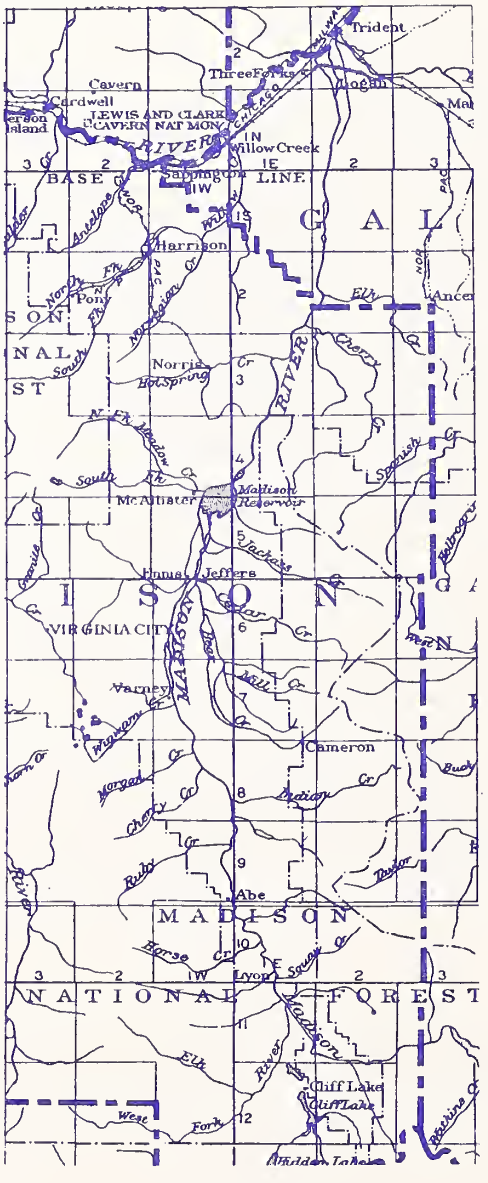


FIG. 17

Madison River Valley.

The aquifer is in alluvium along the Madison River.

Area of aquifer .... 50,000 acres
Specific yield of aquifer .... .15
Average aquifer thickness (saturated thickness) .... 35(b) feet
Average thickness permeable alluvium .... 100(b) feet +
Transmissibility .... gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER 54

Madison River Valley
Drainage basin 41F

Precipitation .... 16 inches annual average
Well depths .... 41 - 620 feet
Water table .... 11 feet to (no figures for deep wells)
Well yields, 12 - 60 gpm. Potential in middle valley .... 1000 gpm
Specific capacities .... .5 - 8.0 gpm/ft.
Number of wells ....
Temperature of well water .... °F
Well uses .... Stock and domestic
Remarks:

References:

Water power and irrigation in the Madison River Basin, Montana: USGS Water-Supply Paper 560-A, 1925.

Well data from groundwater files: Montana Water Resources Board.

INDEX MAP NUMBER 55

Jefferson River Valley
Drainage basin 41G

Groundwater in storage, available to wells .... 110,000(b) acre-feet
Perennial recharge .... 18,000(b) acre-feet
Quality—Domestic 1, Irrigation 1

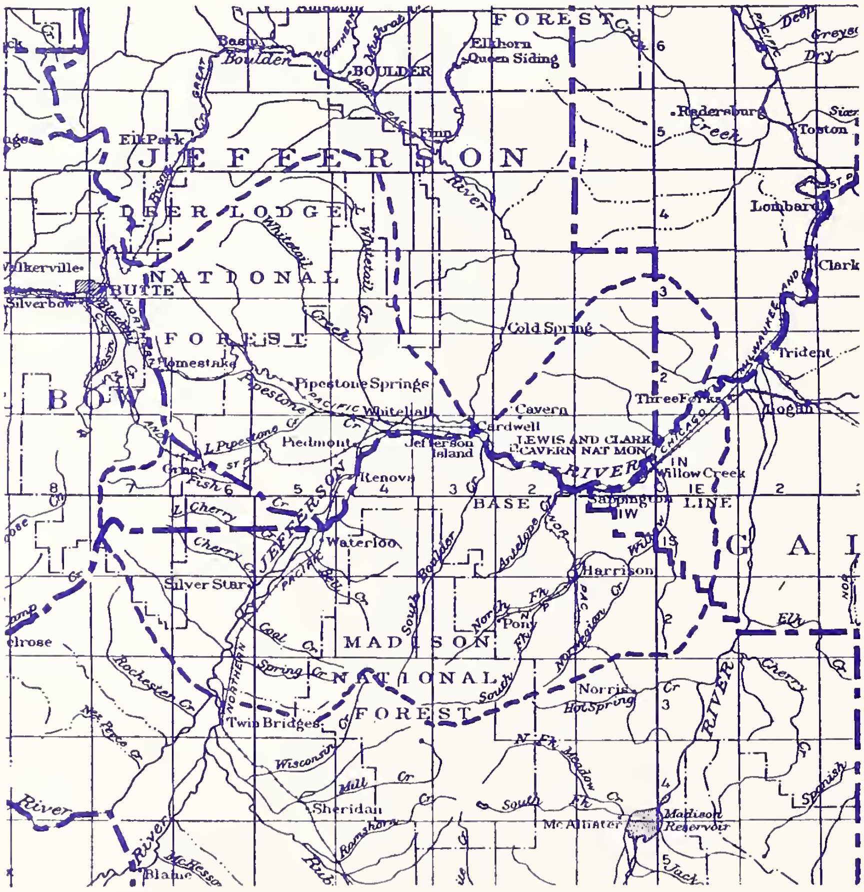


FIG. 18

Outline of Jefferson River Basin.

The aquifer is in alluvium of Jefferson River and major tributaries.

Area of aquifer .... 45,000 acres
Specific yield of aquifer .... .10(b)
Average aquifer thickness (saturated thickness) .... 25(b) feet
Average thickness permeable alluvium .... 50(b) feet
Transmissibility .... gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER 55

Jefferson River Valley
Drainage basin 41G

Precipitation	12 inches annual average
Well depths	38 - 169 feet
Water table	4 - 56 feet
Well yields, 10 - 30 gpm	potential at least 250 gpm
Specific capacities	gpm/ft.
Number of wells	
Temperature of well water	°F
Well uses	Chiefly stock and domestic

Remarks:

References:

Water power and irrigation in the Jefferson River Basin, Montana: USGS Water-Supply Paper 560-B, 1926.

Well data from groundwater files: Montana Water Resources Board.

INDEX MAP NUMBER 31

Gallatin Valley
Drainage basin 41H

Groundwater in storage, available to wells .... 1,600,000(b) acre-feet
Perennial recharge .... 240,000(b) acre-feet
Quality—Domestic 1, Irrigation 1

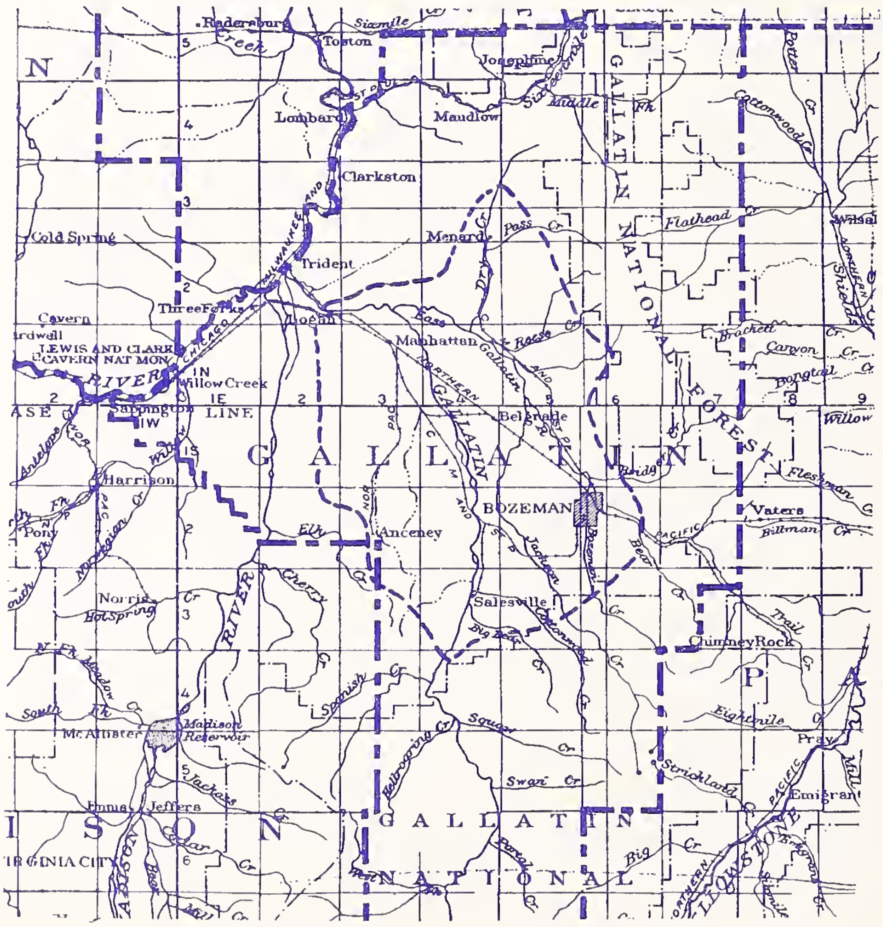


FIG. 19

Map showing Gallatin Valley report area enclosed by dashed line.

The aquifer is in alluvium bordering the Gallatin River and major tributaries.

Area of aquifer .... 107,000 acres
Specific yield of aquifer .... .15
Average aquifer thickness (saturated thickness) .... 100(b) feet
Average thickness of permeable alluvium .... 125 feet
Transmissibility .... 30,000+670,000 gpd/ft. (av. 200,000)

SPECIFIC INFORMATION
INDEX MAP NUMBER 31

Gallatin Valley
Drainage basin 41H

Precipitation .... Annual average 18 inches, or 479,000 acre-feet, a 15 year average

Well depths .... 10 - 105 feet

Water table .... 5 - 25 feet

Well yields .... 16 - 2000 gpm

Specific capacities (average of 5 irrigation wells) .... 98 gpm/ft.

Number of wells .... 1100+

Temperature of well water .... 44° - 59° F

Well uses ....Chiefly domestic and stock

Remarks: Waterlogged acres—17,000+

Discharge by springs, 70,000 ac-ft/yr.

Discharge by evapotranspiration, 30,000 to 90,000 ac-ft/yr.

References:

Geology and ground-water resources of the Gallatin Valley, Gallatin County, Montana: USGS Water-Supply Paper 1482, 1960.

Groundwater appropriation files: Montana Water Resources Board, Helena.

INDEX MAP NUMBERS 5, 24

Townsend Valley
Drainage basin 41 I

Groundwater in storage, available to wells	110,000(b) acre-feet
Perennial recharge	16,000(b) acre-feet

Quality—Domestic 1-5, Irrigation 2-3

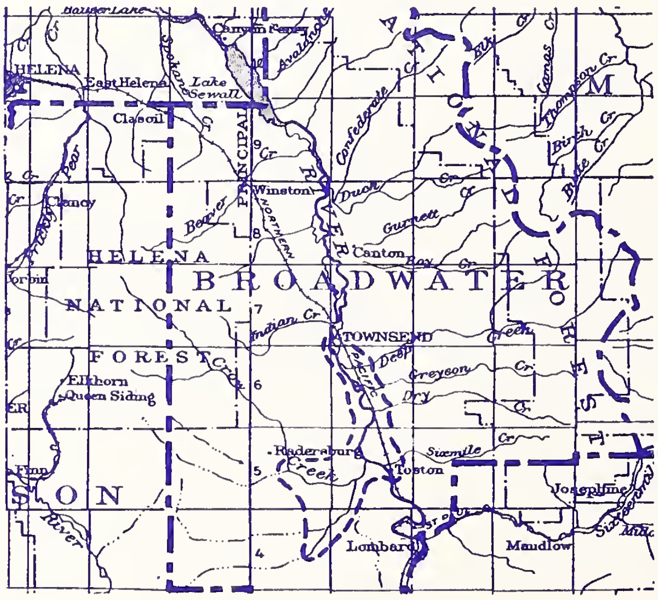


FIG. 20

Townsend Valley with area of alluvial aquifer outlined.

Area of aquifer	37,000(b) acres
Specific yield of aquifer	.15(b)
Average aquifer thickness (saturated thickness)	20(b) feet
Average thickness permeable alluvium	100 feet+
Transmissibility	gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBERS 5, 24

Townsend Valley
Drainage basin 41 I

Precipitation	12 inches annual average
Well depths	20 - 200 feet
Water table	1 - 171 feet
Well yields	8 - 10 gpm
Specific capacities	gpm/ft.
Number of wells	530+
Temperature of well water	°F
Well uses	Chiefly stock and domestic

Remarks: 7,000 acres waterlogged.

References:

Geology and groundwater resources of the Townsend Valley, Montana: USGS Water-Supply Paper 539, 1925.

Geology and occurrence of groundwater in the Townsend Valley, Montana, with a section on the chemical quality of the water: USGS Water-Supply Paper 1360-C, 1956.

INDEX MAP NUMBER 21

Helena Valley
Drainage basin 41 I

Groundwater in storage, available to wells .... 150,000(b) acre-feet
Perennial recharge .... 18,000(b) acre-feet
Quality—Domestic 1, Irrigation 1-2

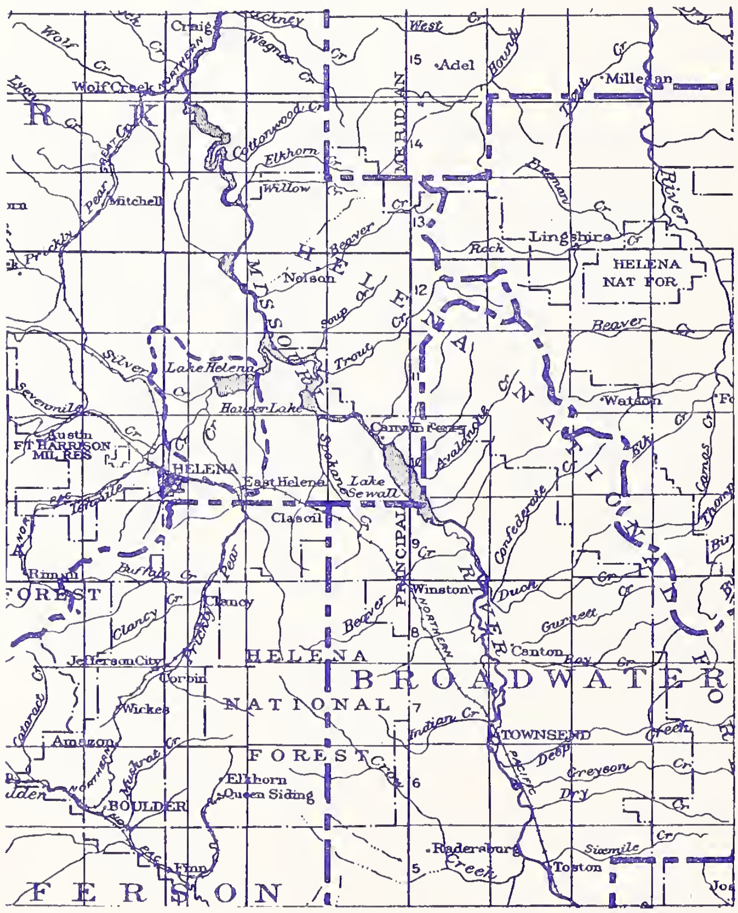


FIG. 21

Helena Valley with alluvial basin outlined.

Area of aquifer .... 20,000 acres
Specific yield of aquifer .... .15(b)
Average aquifer thickness (saturated thickness) .... 50(b) feet
Average thickness permeable alluvium ....100 feet +
Transmissibility .... gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER 21

Helena Valley
Drainage basin 41 I

Precipitation	12 inches annual average
Well depths	8 - 408 feet
Water table	1 - 67 feet
Well yields, 150 - 300 gpm, flows 25 - 125 gpm	potential 1000 gpm
Specific capacities	gpm/ft.
Number of wells	120+
Temperature of well water	°F
Well uses	Chiefly stock and domestic

Remarks:

References:

Geology and groundwater resources of the Helena Valley, Montana: USGS Circ. 83, 1951.

INDEX MAP NUMBER 44

White Sulphur Springs area
Drainage basin 41J

Groundwater in storage, available to wells .... 40,000(b) acre-feet
Perennial recharge .... 8,000(b) acre-feet
Quality—Domestic 1, Irrigation 1-3

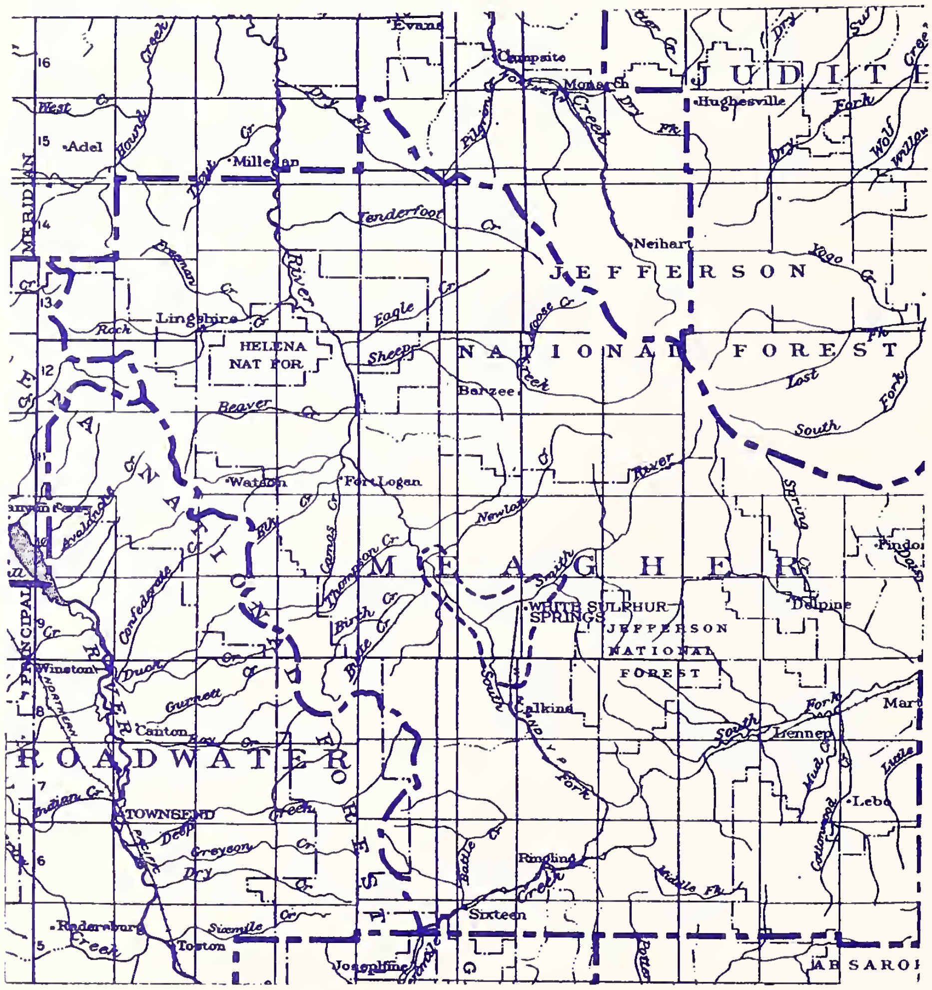


FIG. 22

General outline of alluvial area in White Sulphur Springs area.

Area of aquifer .... 10,000(b) acres
Specific yield of aquifer .... .20(b)
Average aquifer thickness (saturated thickness) .... 20(b) feet
Average thickness permeable alluvium .... 30(b) feet
Transmissibility .... gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER 44

White Sulphur Springs area
Drainage basin 41J

Precipitation .... 18 inches annual average

Well depths .... 12 - 300 feet

Water table .... 5 - 100 feet

Well yields .... to 1,850 gpm

Specific capacities .... gpm/ft.

Number of wells .... 90+

Temperature of well water .... °F

Well uses .... Chiefly stock and domestic. Several irrigation wells.

Remarks: Tertiary channels are the most important with respect to large yields, but the area they occupy is unknown, because they can be located only by drilling. Therefore, no storage nor recharge figures can be computed.

References:

Reconnaissance groundwater and geological studies, Western Meagher County, Montana: MBMG Spec. Pub. 35, 1965.

INDEX MAP NUMBERS 48, 39

Cascade-Ulm area, Smith River Valley
Drainage basin 41J

Groundwater in storage, available to wells	22,000(b) acre-feet
Perennial recharge	3,000(b) acre-feet

Quality—Domestic 1, Irrigation 1

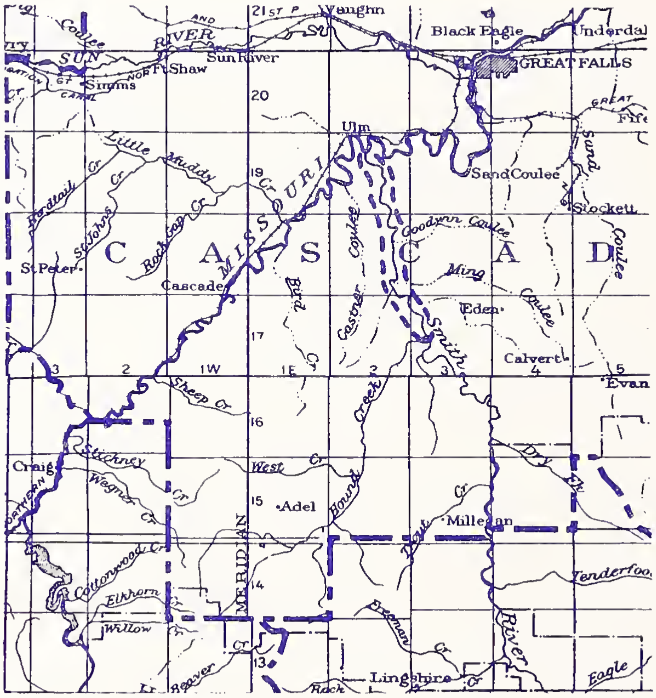


FIG. 23

General outline of the area of the aquifer in Smith River Valley alluvium.

Area of aquifer	6,000(b) acres
Specific yield of aquifer	.15(b)
Average aquifer thickness (saturated thickness)	25(b) feet
Average thickness permeable alluvium	50(b) feet
Transmissibility	gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBERS 48, 39

Cascade-Ulm area, Smith River Valley
Drainage basin 41J

Precipitation	15 inches annual average
Well depths	11 - 205 feet
Water table	2 - 190 feet
Well yields	4 - 46 gpm
Specific capacities	gpm/ft.
Number of wells	16+
Temperature of well water	°F
Well uses	Chiefly stock and domestic

Remarks: Computations only for Smith River alluvium.

References:

Geology and groundwater resources of the Cascade-Ulm area, Montana: MBMG Bull. 52, 1966.

Hydrology of the Cascade-Ulm area: Unpublished thesis, University of Montana, 1963.

INDEX MAP NUMBER 1

Lower Sun River Valley
Drainage basin 41K

Groundwater in storage, available to wells	180,000(b) acre-feet
Perennial recharge	30,000(b) acre-feet

Quality—Domestic 1, Irrigation 1

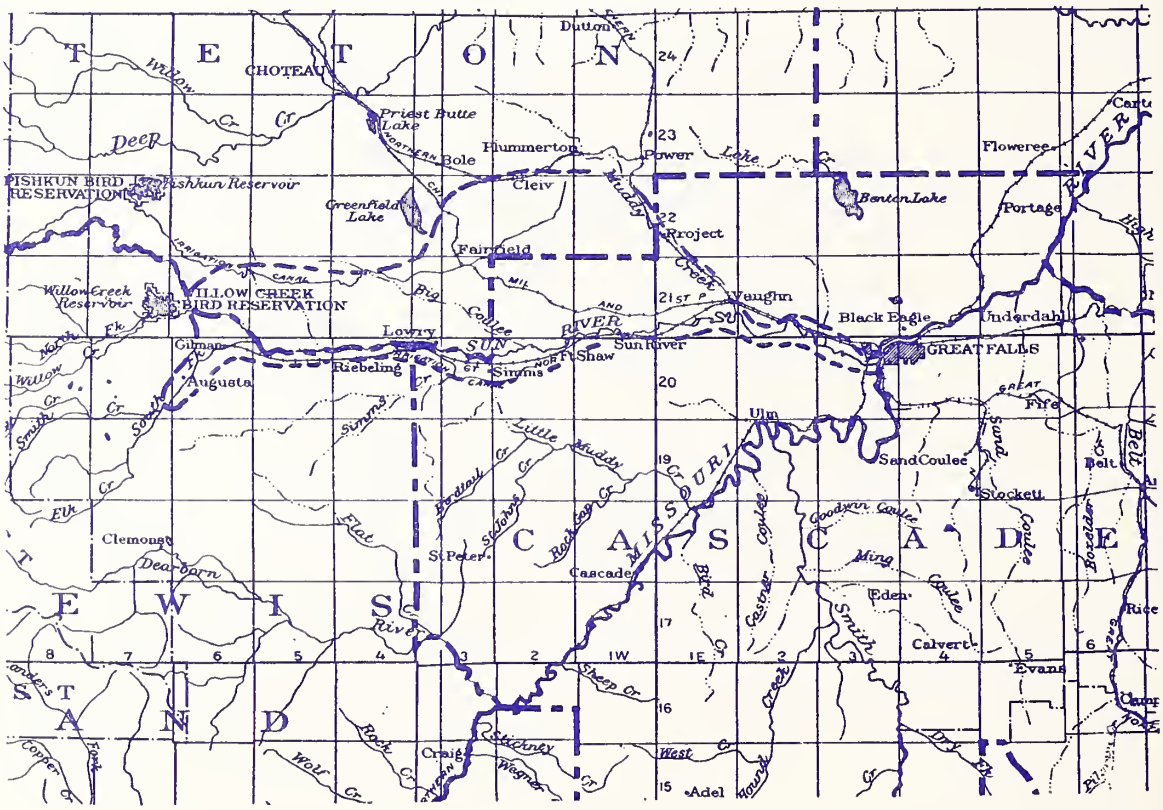


FIG. 24

Lower Sun River alluvial, enclosed by dashed line.

Area of aquifer	122,000 acres
Specific yield of aquifer	.15(b)
Average aquifer thickness (saturated thickness)	10(b) feet
Average thickness permeable alluvium	35(b) feet
Transmissibility	gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER 1

Lower Sun River Valley
Drainage basin 41K

Precipitation	14 inches annual average
Well depths	12 - 187 feet
Water table	5 - 60 feet
Well yields, 5 - 60 gpm	potential 250 - 1000 gpm
Specific capacities (one only)	1.6 gpm/ft.
Number of wells	
Temperature of well water	°F
Well uses	Chiefly stock and domestic

Remarks:

References:

Geology and water resources of the Great Falls region, Montana: USGS Water-Supply Paper 221, 1909.

Water Resources Survey, Cascade County, Montana: State Engineer's Office, Helena, Montana, 1961.

Water Resources Survey, Lewis and Clark County, Montana: State Engineer's Office, Helena, Montana, 1957.

Water Resources Survey, Teton County, Montana: State Engineer's Office, Helena, Montana, 1962.

Mineral and water resources of Montana: USGS and MBMG Spec. Pub. 28, 1963.

Well data from groundwater files, Montana Water Resources Board.

Montana Highway Department test hole logs.

INDEX MAP NUMBER 1

Lower Teton River Valley
Drainage basin 41-O

Groundwater in storage, available to wells .... 75,000(b) acre-feet
Perennial recharge .... 12,000(b) acre-feet
Quality—Domestic 1-3, Irrigation 1-3

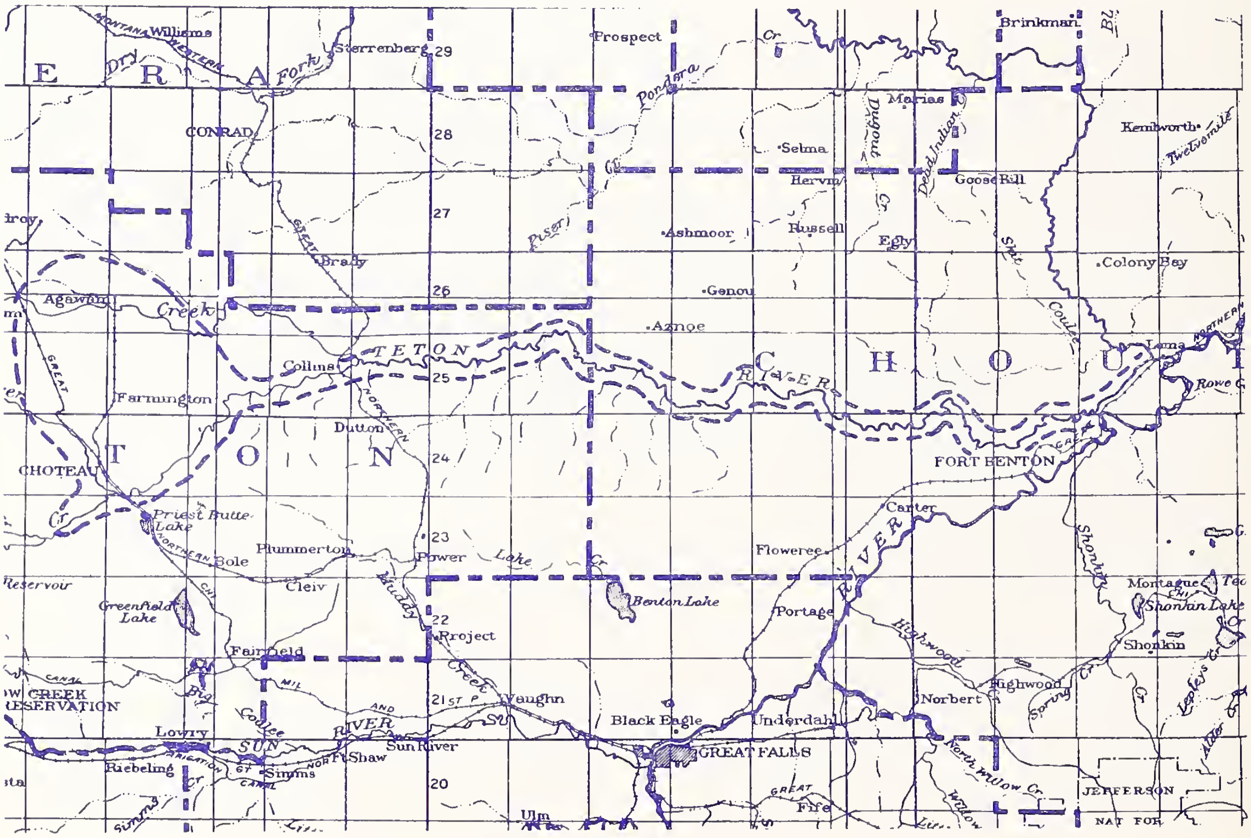


FIG. 25

Lower Teton River alluvial aquifer, enclosed by dashed line.

Area of aquifer .... 51,000 acres
Specific yield of aquifer .... .15(b)
Average aquifer thickness (saturated thickness) ....10(b) feet
Average thickness permeable alluvium .... 30(b) feet
Transmissibility .... gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER 1

Lower Teton River Valley
Drainage basin 41-O

Precipitation	12 inches annual average
Well depths	10 - 135 feet
Water table	6 - 40 feet
Well yields	5 - 70 gpm
Specific capacities	gpm/ft.
Number of wells	
Temperature of well water	°F
Well uses	Stock and domestic

Remarks:

References:

Geology and water resources of the Great Falls region, Montana: USGS Water-Supply Paper 221, 1909.

Water Resources Survey, Chouteau County, Montana: State Engineer's Office, Helena, Montana, 1964.

Water Resources Survey, Teton County, Montana: State Engineer's Office, Helena, Montana, 1962.

Well data from groundwater files, Montana Water Resources Board.

INDEX MAP NUMBERS 48, 39

Cascade-Ulm area, Missouri River Valley
Drainage basin 41 Q J

Groundwater in storage, available to wells .... 135,000(b) acre-feet
Perennial recharge .... 20,000(b) acre-feet
Quality—Domestic 1, Irrigation 1

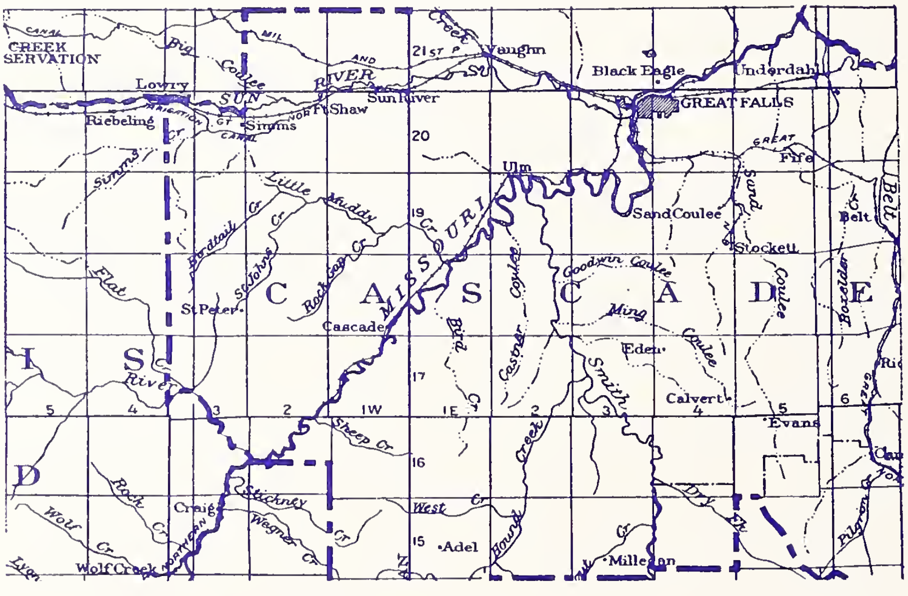


FIG. 26

Report Area.

The aquifer is in alluvium bordering the Missouri River.

Area of aquifer .... 36,000(b) acres
Specific yield of aquifer .... .15(b)
Average aquifer thickness (saturated thickness) .... 25(b) feet
Average thickness permeable alluvium .... 70(b) feet
Transmissibility .... gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBERS 48, 39

Cascade-Ulm area, Missouri River Valley
Drainage basin 41 Q J

Precipitation .... 15 inches annual average

Well depths .... 11 - 200 feet

Water table .... 4 - 55 feet

Well yields, flows to 30 gpm ....On pump—1 - 70 gpm

Specific capacities .... gpm/ft.

Number of wells .... 47+

Temperature of well water ....°F

Well uses .... Chiefly stock and domestic, several irrigation wells

Remarks: This area totals 42,000 acres, 36,000 acres is in the Missouri Drainage, basin 41 Q J, and 6,000 acres is in the Smith River drainage, basin 41J.

References:

Geology and groundwater resources of the Cascade-Ulm area, Montana: MBMG Bull. 52, 1966.

Hydrology of the Cascade-Ulm area: Unpublished thesis, University of Montana, 1963.

INDEX MAP NUMBERS 10, 38, 46, 47

Judith Basin

Drainage basins 41R, 41S

Groundwater in storage, available to wells .... unknown acre-feet

Perennial recharge .... unknown acre-feet

Quality—Domestic 1-4, Irrigation 1-3

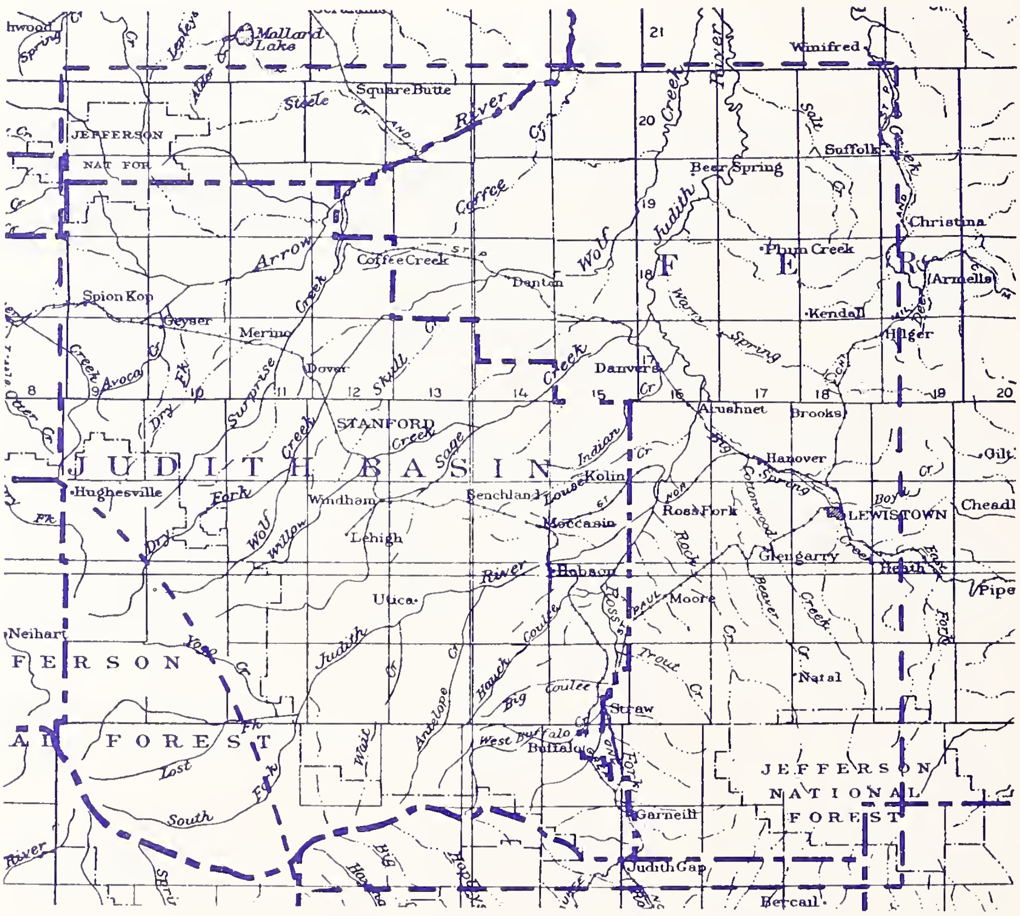


FIG. 27

General outline of Judith Basin report areas.

Area of aquifer .... unknown acres

Specific yield of aquifer ....

Average aquifer thickness (saturated thickness) .... unknown

Average thickness permeable alluvium .... unknown

Transmissibility .... 4,600 - 30,000 gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBERS 10, 38, 46, 47

Judith Basin
Drainage basins 41R, 41S

Precipitation .... 12 inches annual average

Well depths .... Alluvium 5 - 40 feet, terrace deposits 9 - 128 feet

Water table .... Alluvium 3 - 36 feet, terrace deposits 2 - 85 feet

Well yields, up to 15 gpm in terrace deposits, alluvium .... 5 - 25 gpm

Specific capacities .... gpm/ft.

Number of wells .... 67+

Temperature of well water.........Terrace deposits, 43° - 71°, alluvium, 43 - 57 °F

Well uses .... Chiefly stock and domestic

Remarks:

Irrigated acreages are small and widespread. Storage and recharge figures were not computed.

Small-scale well irrigation is possible in lower valleys of Wolf Creek and Judith River.

References:

Groundwater resources of Judith Basin, Montana: MBMG Mem. 7, 1932.

Preliminary report on the geology and groundwater resources of southern Judith Basin, Montana: MBMG Bull. 32, 1962.

Geology and groundwater resources of western and southern parts of Judith Basin, Montana: MBMG Bull. 50A, 1966.

Basic water data report no. 2, western and southern parts of Judith Basin, Montana: MBMG Bull. 50B, 1966.

INDEX MAP NUMBER 6

Yellowstone River Valley
Drainage basin 42 K J

Groundwater in storage, available to wells .... 33,000(b) acre-feet
Perennial recharge .... 5,000(b) acre-feet
Quality—Terrace deposits Domestic 1, Irrigation 1
Alluvium Domestic 3-5, Irrigation, 1-5

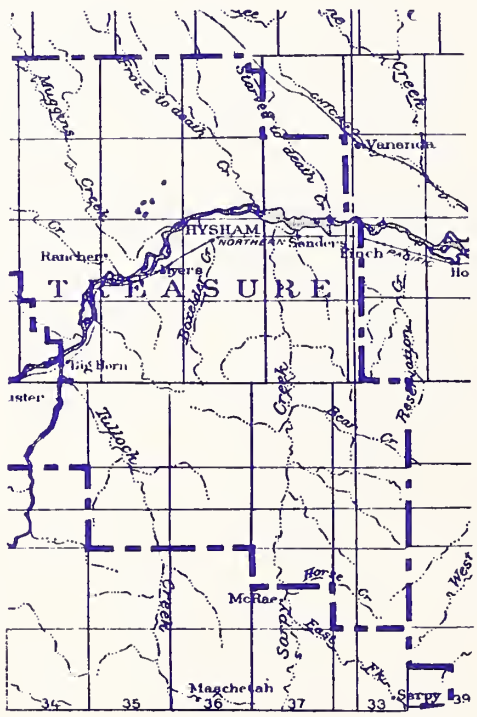


FIG. 28

Report Area.

The aquifer is in alluvium along Yellowstone River, from the vicinity of Big Horn east to the Treasure County line.

Area of aquifer .... 25,000 acres
Specific yield of aquifer .... .15(b)
Average aquifer thickness (saturated thickness) .... 9(b) feet
Average thickness permeable alluvium .... 40(b) feet
Transmissibility .... gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER 6

Yellowstone River Valley
Drainage basin 42 K J

Precipitation	12 inches annual average
Well depths	6 - 60 feet
Water table	4 - 50 feet
Well yields	Small to moderate
Specific capacities	gpm/ft.
Number of wells	16+
Temperature of well water	°F
Well uses	Chiefly stock and domestic

Remarks:

References:

Groundwater in Yellowstone and Treasure Counties, Montana: USGS Water-Supply Paper 599, 1929.

Water Resources Survey, Treasure County, Montana: State Engineer's Office, Helena, 1951.

Irrigation districts, Yellowstone County, Montana: Billings Commercial Club, 1943.

INDEX MAP NUMBER 7

Yellowstone River Valley
Drainage basin 42 K J

Groundwater in storage, available to wells .... 33,000(b) acre-feet
Perennial recharge .... 6,000(b) acre-feet
Quality—Terrace deposits, Domestic 1, Irrigation 1
Alluvium, Domestic 3-5, Irrigation 1-5

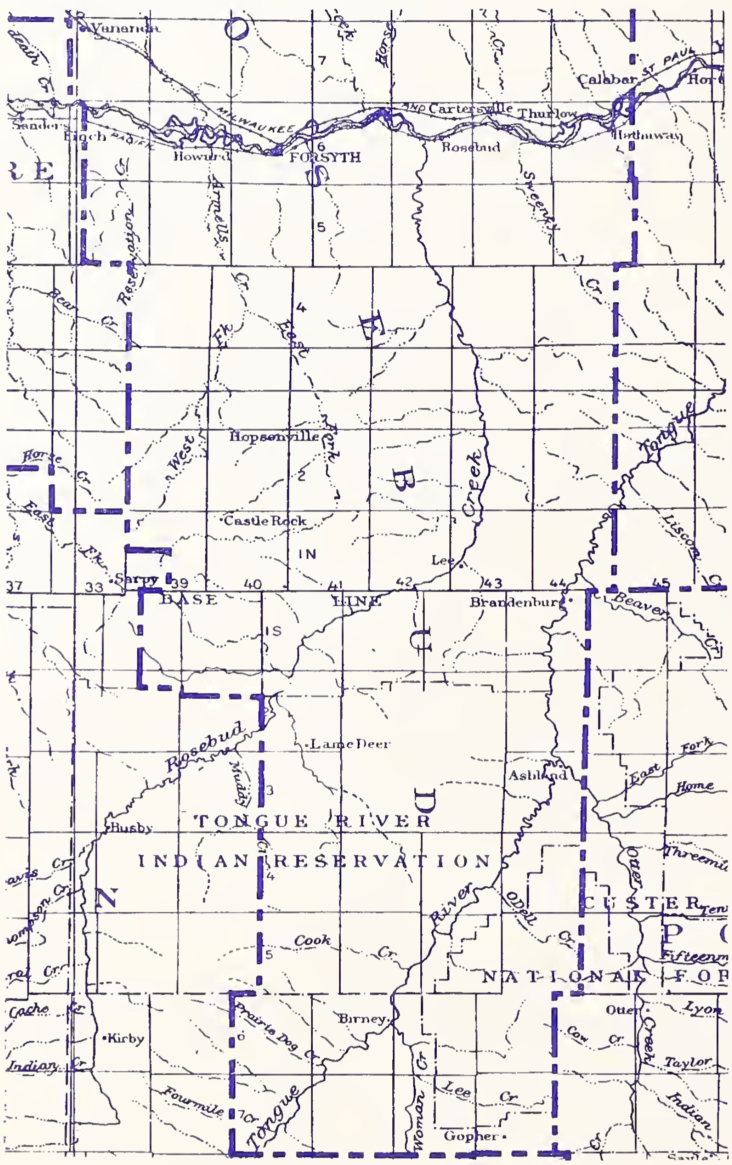


FIG. 29

Report Area.

Aquifer is in alluvium bordering the Yellowstone River.

Area of aquifer .... 22,000(b) acres
Specific yield of aquifer .... .15(b)
Average aquifer thickness (saturated thickness) .... 10(b) feet
Average thickness permeable alluvium .... 30(b) feet
Transmissibility .... gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER 7

Yellowstone River Valley
Drainage basin 42 K J

Precipitation .... 14 inches annual average
Well depths .... 8 - 70 feet in alluvium
Water table .... 3 - 34 feet
Well yields, 5 gpm ....potential yields 100 gpm
Specific capacities .... gpm/ft.
Number of wells .... 43+
Temperature of well water ....°F
Well uses .... Chiefly stock and domestic
Remarks: Total area of alluvium and terraces is 160,000+ acres.

References:

Geology and groundwater resources of central and southern Rosebud County, Montana: USGS Water-Supply Paper 600, 1929.

Water Resources Survey, Rosebud County, Montana: State Engineer's Office, Helena, Montana, 1948.

INDEX MAP NUMBERS 22, 13

Yellowstone River Valley
Drainage basin 42K

Groundwater in storage, available to wells .... 28,000 acre-feet
Perennial recharge .... 8,000 acre-feet
Quality—Domestic 1-3, Irrigation 1-5

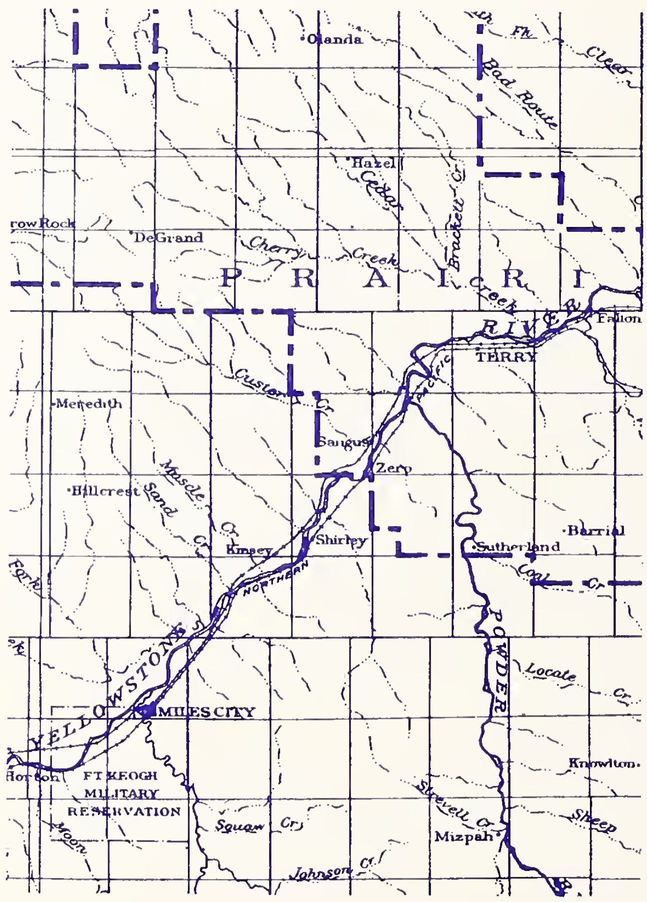


FIG. 30

Area Summarized.

The aquifer is in alluvium from Miles City east to the mouth of the Powder River.

Area of aquifer .... 24,000 acres
Specific yield of aquifer .... .15(b)
Average aquifer thickness (saturated thickness) .... 8(b) feet
Average thickness permeable alluvium .... 35+ feet
Transmissibility .... gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBERS 22, 13

Yellowstone River Valley
Drainage basin 42K

Precipitation .... 13 inches annual average
Well depths .... alluvium, 10 - 40 feet, terrace deposits, 10 - 100 feet
Water table .... 2 - 18 feet
Well yields .... potential of more than 250 gpm near Miles City
Specific capacities .... gpm/ft.
Number of wells .... 122+
Temperature of well water .... °F
Well uses .... Chiefly stock and domestic
Remarks:

References:

Groundwater resources of the Yellowstone River Valley between Miles City and Glendive, Montana: USGS Circ. 93, 1951.

Groundwater resource map of Prairie County, Montana: MBMG (map only), 1934.

INDEX MAP NUMBERS 29, 8, 22

Yellowstone River Valley
Drainage basin 42M

Groundwater in storage, available to wells .... 39,000(b) acre-feet
Perennial recharge .... 11,000(b) acre-feet
Quality—Domestic 3-5, Irrigation 3-5

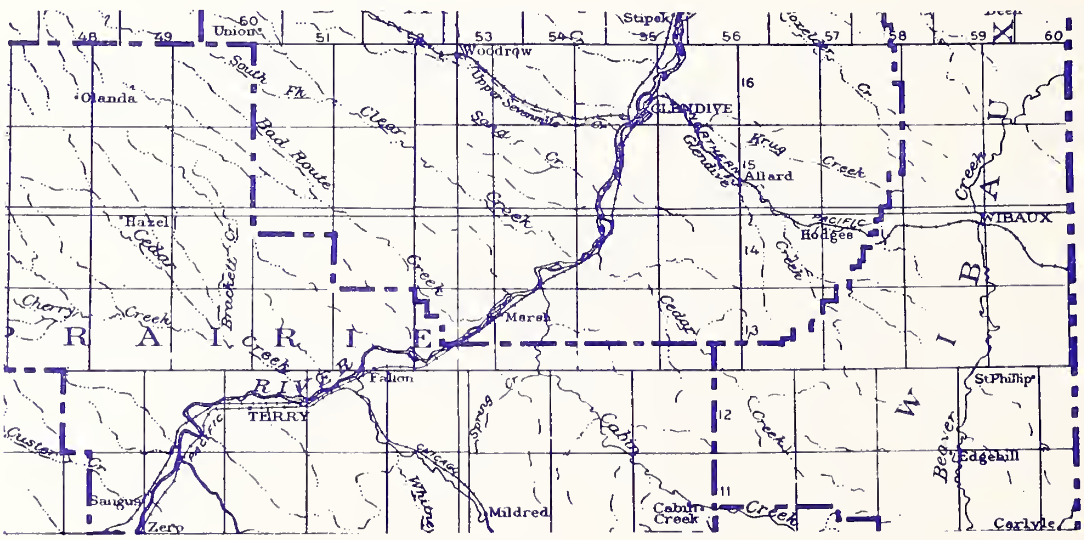


FIG. 31

Report Area.

The aquifer is in Yellowstone Valley unconsolidated deposits from the mouth of the Powder River west of Terry, downstream to Glendive.

Area of aquifer .... 26,000(b) acres
Specific yield of aquifer .... .15
Average aquifer thickness (saturated thickness) .... 10(b) feet
Average thickness permeable alluvium .... 25(b) feet
Transmissibility .... 5200 - 250,000 gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBERS 29, 8, 22

Yellowstone River Valley
Drainage basin 42M

Precipitation	14 inches annual average
Well depths	6 - 135 feet
Water table	1 - 35 feet
Well yields	250 to 466 gpm near Terry
Specific capacities	gpm/ft.
Number of wells	325+
Temperature of well water	°F
Well uses	Chiefly stock and domestic

Remarks: Coefficient of Storage—S = .00016 to .023. Irrigated acres, 20,000. Waterlogging is prevalent.

References:

Groundwater factors affecting drainage in the first division, Buffalo Rapids irrigation project, Prairie and Dawson Counties, Montana: USGS Water-Supply Paper 1424, 1958.

Shallow wells near Terry, Montana, as a source of irrigation water: MBMG Misc. Cont. 3, 1932.

Groundwater resources of the lower Yellowstone River Valley between Miles City and Glendive: USGS Circ. 93, 1951.

INDEX MAP NUMBER 26

Yellowstone River Valley
Drainage basin 42M

Groundwater in storage, available to wells .... 132,000(b) acre-feet
Perennial recharge .... 22,000(b) acre-feet
Quality—Domestic 1-5, Irrigation 1-5

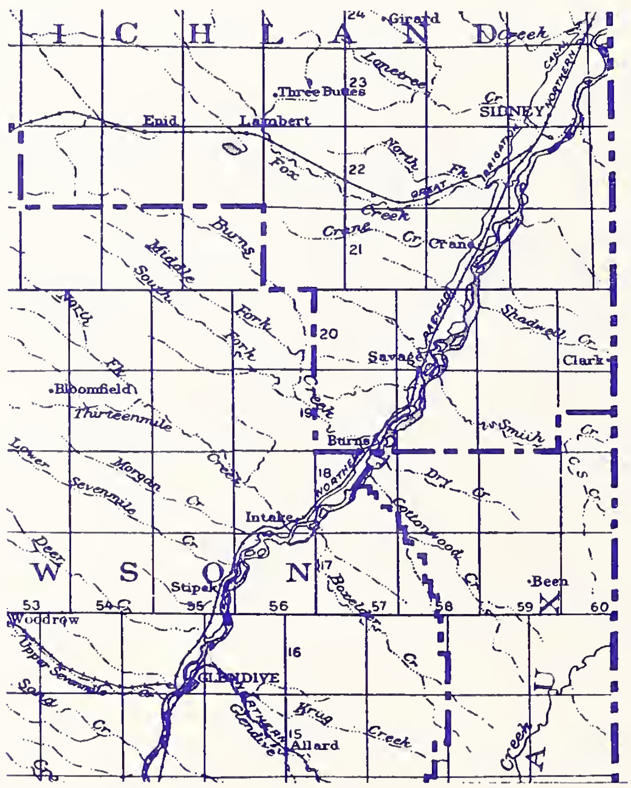


FIG. 32

Report Area.

The aquifer is in unconsolidated deposits bordering the river between Glendive and Sidney.

Area of aquifer .... 76,000 acres
Specific yield of aquifer .... .15
Average aquifer thickness (saturated thickness) .... 12(b) feet
Average thickness permeable alluvium .... 40(b) feet
Transmissibility .... gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER 26

Yellowstone River Valley
Drainage basin 42M

Precipitation .... 14 inches annual average
Well depths .... 19-81 feet
Water table .... 7-53 feet
Well yields .... Sufficient for stock and domestic use
Potential in excess of 250 gpm
Specific capacities .... gpm/ft.
Number of wells .... 314+
Temperature of well water .... °F
Well uses .... Chiefly stock, domestic, and municipal
(Sidney—200,000 to 1,000,000 gpd—municipal use)

Remarks: Potential exists for relatively large yields from wells in terraces. Alluvial wells show relatively low permeabilities in some areas. Irrigated acreages in Dawson and Richland Counties total 55,000+.

References:

Geology and groundwater resources of the Yellowstone River Valley between Glendive and Sidney, Montana: USGS Water-Supply Paper 1355, 1956.

Unpublished data on irrigated acreages in Montana: Montana Water Resources Board, Helena.

INDEX MAP NUMBER 36

Shields River Valley
Drainage basin 43A

Groundwater in storage, available to wells .... 6,000(b) acre-feet
Perennial recharge .... 1,000(b) acre-feet
Quality—Domestic - Satisfactory

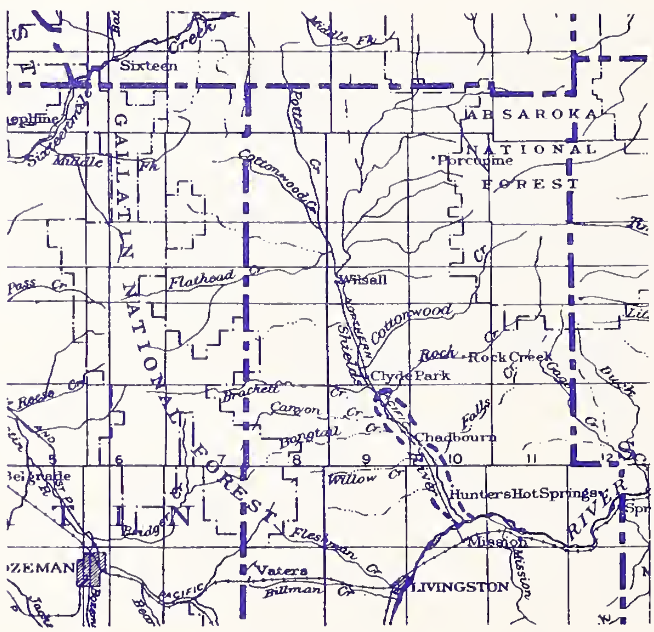


FIG. 33

Northern Park County.

The aquifer area is outlined in lower Shields River Valley alluvium.

Area of aquifer .... 2000(b) acres
Specific yield of aquifer .... alluvium .15(b)
Average aquifer thickness (saturated thickness) .... 20(b) feet
Average thickness permeable alluvium .... 52 feet
Transmissibility .... gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER 36

Shields River Valley
Drainage basin 43A

Precipitation	14 inches annual average
Well depths	Alluvium— 6 - 48 feet
	Livingston Fm.—13 - 315 feet
Water table	Alluvium— 2 - 20 feet
	Livingston Fm.— 5 - 275 feet
Well yields	Alluvium—12 - 640 gpm
	Livingston Fm.— 8 - 10 gpm
Specific capacities	gpm/ft.
Number of wells	100+
Temperature of well water	°F
Well uses	Chiefly stock and domestic

Remarks: Potential yields of 1000 gpm from alluvium in T. 1 N., R. 9 E., Sec.

Computations for Shields River alluvium only.

References:

Reconnaissance groundwater studies, Northern Park County, Montana: MBMG Spec. Pub. 26, 1962.

INDEX MAP NUMBER 36

Yellowstone River Valley

Drainage basin 43B

Groundwater in storage, available to wells .... 30,000(b) acre-feet

Perennial recharge .... 5,000(b) acre-feet

Quality—Domestic - Satisfactory

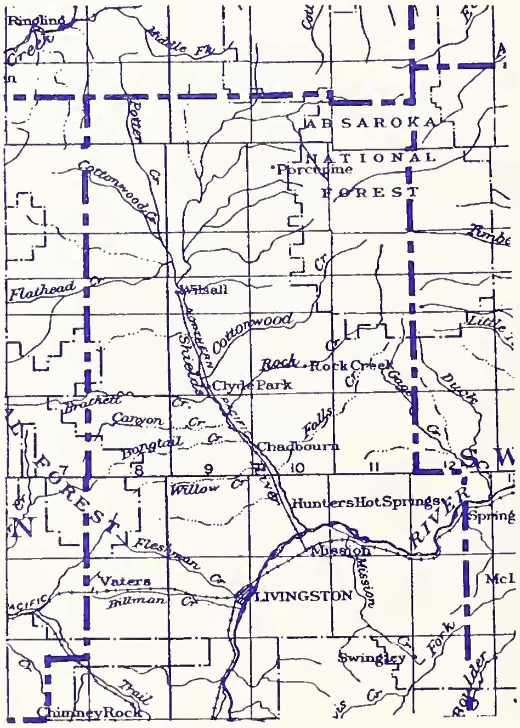


FIG. 34

Northern Park County.

The aquifer borders the Yellowstone River in alluvium from the Livingston area downstream to the Park County line.

Area of aquifer .... 10,000(b) acres

Specific yield of aquifer .... .15(b)

Average aquifer thickness (saturated thickness) .... 20(b) feet

Average thickness permeable alluvium .... 52 feet

Transmissibility .... gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER 36

Yellowstone River Valley
Drainage basin 43B

Precipitation	14 inches annual average
Well depths	Alluvium— 8 - 52 feet
	Livingston Fm.—30 - 140 feet
Water table	Alluvium— 6 - 23 feet
	Livingston Fm.— 5 - 88 feet
Well yields	Alluvium 19 - 900 gpm
	Livingston Fm. 5 - 800 gpm
Specific capacities	gpm/ft.
Number of wells	25+
Temperature of well water	°F
Well uses	Chiefly stock and domestic, 3 municipal wells

Remarks: Potential yields of 1000 gpm from alluvium.
Hunter's Hot Springs flows at 1500 gpm, excellent quality for irrigation.
Storage and recharge computations for Yellowstone River alluvium only.

References:

Reconnaissance groundwater studies, Northern Park County, Montana: MBMG Spec. Pub. 26, 1962.

INDEX MAP NUMBER 35

Yellowstone River Valley
Drainage basin 43B

Groundwater in storage, available to wells .... 40,000(b) acre-feet
Perennial recharge .... 6,800(b) acre-feet
Quality—Domestic - Satisfactory

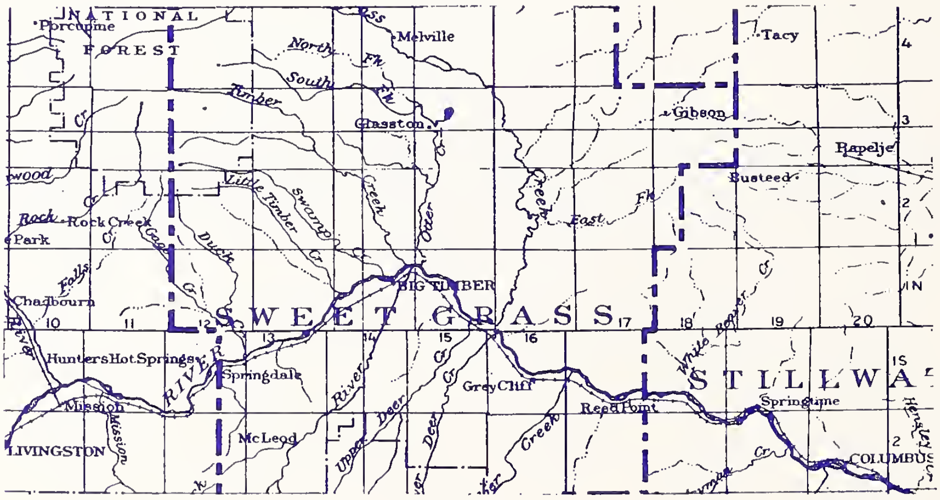


FIG. 35

A Portion of the Report Area.

The aquifer borders the Yellowstone River in alluvium from the west line of Sweet Grass County downstream to about five miles east of Greycliff.

Area of aquifer .... 18,000(b) acres
Specific yield of aquifer .... .15(b)
Average aquifer thickness (saturated thickness) .... 15(b) feet
Average thickness permeable alluvium .... 30(b) feet
Transmissibility .... gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER 35

Yellowstone River Valley
Drainage basin 43B

Precipitation	14 inches annual average
Well depths	10 - 60 feet
Water table	6 - 12 feet
Well yields	Small to moderate
Specific capacities	gpm/ft.
Number of wells	36+
Temperature of well water	°F
Well uses	Chiefly stock and domestic

Remarks: Computations based on Yellowstone River alluvium.

References:

Reconnaissance groundwater studies in Wheatland, eastern Meagher, and northern Sweet Grass Counties, Montana: MBMG Spec. Pub. 24, 1962.

Montana Highway Department test hole logs.

INDEX MAP NUMBER

Clarks Fork and Rock Creek Valleys

Drainage basin 43D

Groundwater in storage, available to wells .... 118,000 acre-feet

Perennial recharge .... 36,000 acre-feet

Quality—Domestic and Irrigation 1-3

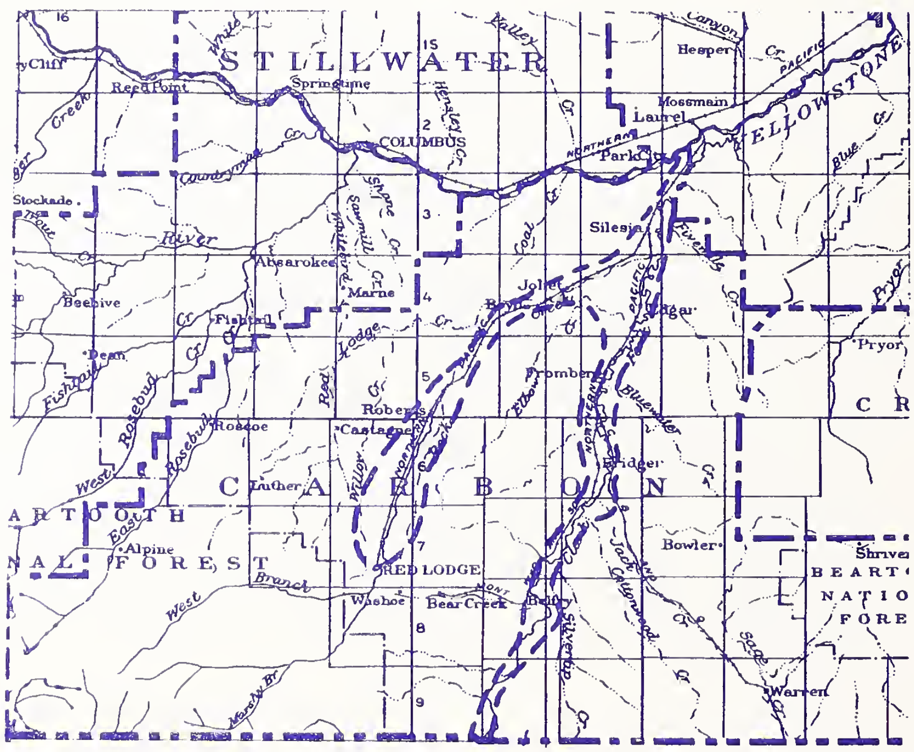


FIG. 36

Carbon County, Montana, with approximate area of Clarks Fork and Rock Creek alluvial deposits enclosed by dashed lines.

Area of aquifer in Clark Fork and Rock Creek alluvial deposits 73,000 acres

Specific yield of aquifer 1

Average aquifer thickness (saturated thickness) .... 16 feet

Average thickness permeable alluvium .... 30 feet

Transmissibility—Clarks Fork alluvium................................ 1400 gpd/ft.

Terraces................................ 2300 gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER

Clarks Fork and Rock Creek Valleys
Drainage basin 43D

Losses ....

Precipitation .... 14 inches annual average

Well depths .... 10 - 74 feet

Water table .... 5 - 43 feet

Well yields ....10 - 300 gpm, potential in terraces 250 - 1000 gpm

Specific capacities ....average 10 gpm/ft.

Number of wells 600

Temperature of well water ....°F

Well uses ....Chiefly stock and domestic, some industrial

Remarks: Use of groundwater from unconsolidated aquifers is estimated at 4700 ac-ft/yr.

References:

Geology and mineral resources of parts of Carbon, Bighorn, Yellowstone and Stillwater Counties, Montana: USGS Bull. 822, 1930.

Water Resources Survey, Carbon County, Montana, State Water Conservation Board, 1966.

*Groundwater Inventory, Carbon County, Montana, Montana Water Resources Board, 1969.

*Source of aquifer data.

INDEX MAP NUMBER 32

Lower Little Bighorn Valley

Drainage basin 43-O

Groundwater in storage, available to wells	23,000 acre-feet
Perennial recharge	7,000 acre-feet

Quality—Domestic 1-5, Irrigation 1-5

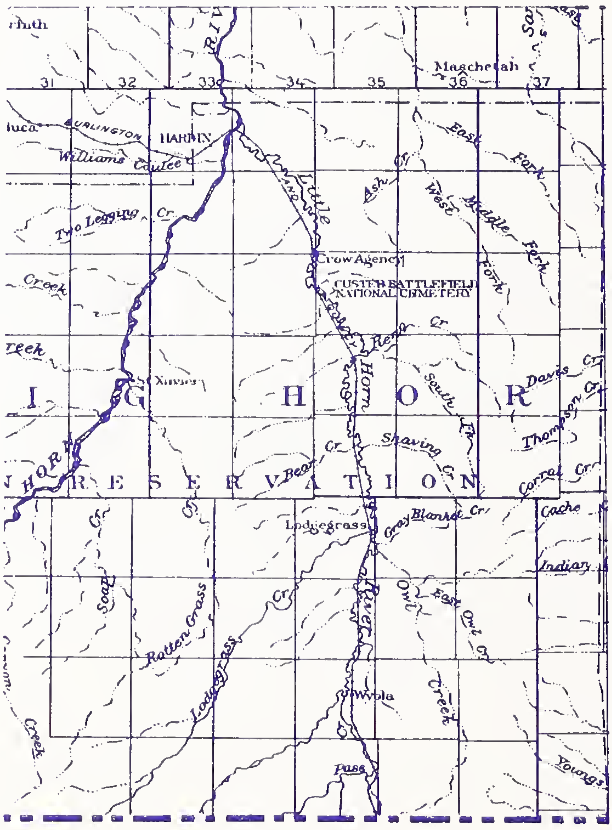


FIG. 37

Little Bighorn Valley.

The aquifer is in unconsolidated deposits bordering the river from Lodge Grass to Hardin.

Area of aquifer	14,000 acres
Specific yield of aquifer	.15
Average aquifer thickness (saturated thickness)	11 feet
Average thickness permeable alluvium	16 feet
Transmissibility	15,000 - 30,000 gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER 32

Lower Little Bighorn Valley
Drainage basin 43-O

Precipitation	12 inches annual average
Well depths	8 - 40 feet
Water table	1 - 30 feet
Well yields, up to 100 gpm	potential up to 300 gpm
Specific capacities	gpm/ft.
Number of wells	200+
Temperature of well water	°F
Well uses	Chiefly stock and domestic

Remarks: Waterlogging is prevalent.

References:

Geology and groundwater resources of the lower Little Bighorn River Valley, Big Horn County, Montana: USGS Water-Supply Paper 1487, 1960.

INDEX MAP NUMBER 52

Lower Bighorn Valley
Drainage basin 43P

Groundwater in storage, available to wells	90,000(b) acre-feet
Perennial recharge	15,000(b) acre-feet

Quality—Domestic 1-5, Irrigation 1-2

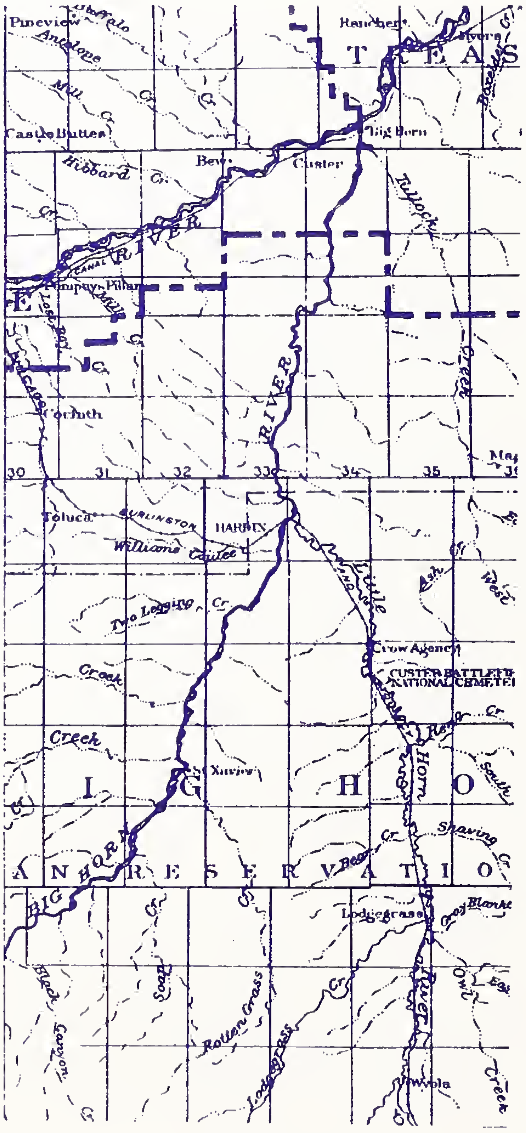


FIG. 38

Lower Bighorn Valley.

The aquifer is in alluvium along the Bighorn River.

Area of aquifer	60,000(b) acres
Specific yield of aquifer	.15(b)
Average aquifer thickness (saturated thickness)	10(b) feet
Average thickness permeable alluvium	30(b) feet
Transmissibility	2,000 - 55,000 gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER 52

Lower Bighorn Valley
Drainage basin 43P

Precipitation	12 inches annual average
Well depths	5 - 55 feet
Water table	1 - 30 feet
Well yields	to 100 gpm. Some flows
Specific capacities	wells in terrace gravels 17 gpm/ft.
Number of wells	270+
Temperature of well water	39 - 68 °F
Well uses	Chiefly stock and domestic

Remarks: Approximately 40,000 irrigated acres.

References:

Geology and groundwater resources of the Lower Bighorn Valley, Montana: USGS Water-Supply Paper 1876, 1968.

INDEX MAP NUMBERS 6, 59

Yellowstone River Valley
Drainage basin 43Q

Groundwater in storage, available to wells .... 167,000(b) acre-feet
Perennial recharge .... 28,000(b) acre-feet
Quality—Domestic 1-5, Irrigation 1-5 in alluvium and terraces

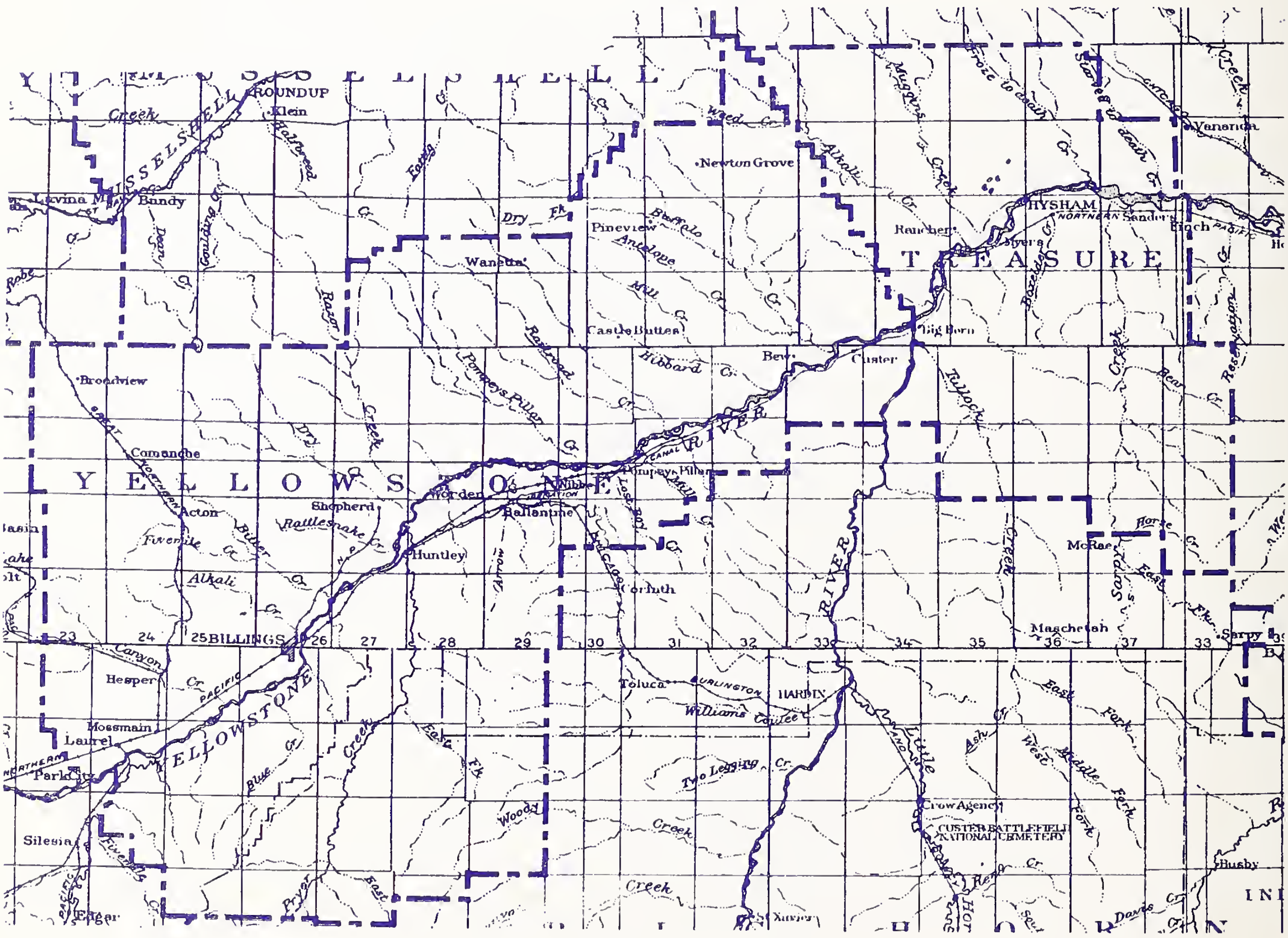


FIG. 39

Map of Report Area.

The aquifer is in alluvium along Yellowstone River in Yellowstone County to the vicinity of Big Horn in Treasure County.

Area of aquifer .... 125,000 acres
Specific yield of aquifer .... .15(b)
Average aquifer thickness (saturated thickness) .... 9(b) feet
Average thickness permeable alluvium .... 40(b) feet
Transmissibility .... gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBERS 6, 59

Yellowstone River Valley
Drainage basin 43Q

Precipitation	12 inches annual average
Well depths	6 - 60 feet
Water table	4 - 50 feet
Well yields	10 - 100 gpm
Specific capacities	gpm/ft.
Number of wells	31+
Temperature of well water	°F
Well uses	Chiefly stock and domestic

Remarks:

Ice manufacture in the Billings area uses less than 500 acre-feet annually.

For river basin breakdown of aquifer in report area, see Figure 2. Unconsolidated aquifers related to drainage basins.

References:

Groundwater in Yellowstone and Treasure Counties, Montana: USGS Water-Supply Paper 599, 1929.

Water Resources Survey, Treasure County, Montana: State Engineer's Office, Helena, Montana, 1951.

Irrigation Districts, Yellowstone County, Montana: Billings Commercial Club, 1943.

Groundwater inventory, Buffalo Creek Cooperative State Grazing District, Yellowstone County: Montana Water Resources Board (in preparation), 1969.

INDEX MAP NUMBER 35

Yellowstone River Valley
Drainage basin 43 Q J

Groundwater in storage, available to wells .... 7,000(b) acre-feet
Perennial recharge .... 1,200(b) acre-feet
Quality—Domestic - Satisfactory

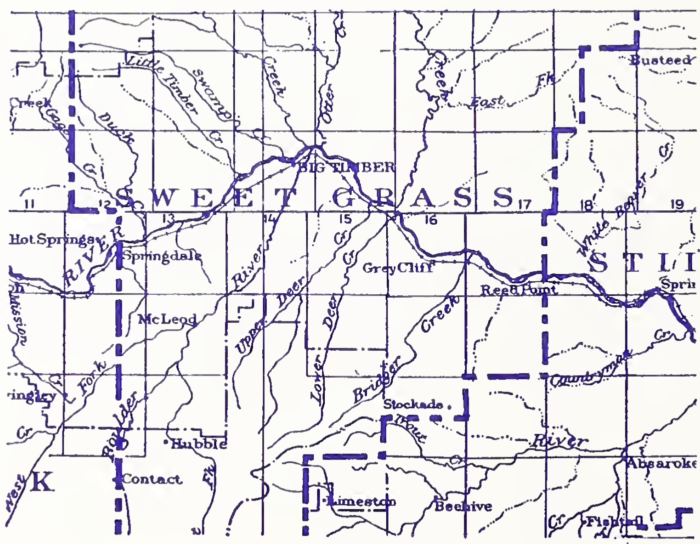


FIG. 40

Portion of the Report Area.

The aquifer is in Yellowstone Valley alluvium from about five miles east of Greycliff, downstream to the Stillwater County line.

Area of aquifer .... 3,000(b) acres
Specific yield of aquifer .... .15(b)
Average aquifer thickness (saturated thickness) .... 15(b) feet
Average thickness permeable alluvium .... 30(b) feet
Transmissibility .... gpd/ft.

SPECIFIC IFORMATION
INDEX MAP NUMBER 35

Yellowstone River Valley
Drainage basin 43 Q J

Precipitation	14 inches annual average
Well depths	10 - 60 feet
Water table	6 - 12 feet
Well yields	Small to moderate
Specific capacities	gpm/ft.
Number of wells	10+
Temperature of well water	°F
Well uses	Chiefly stock and domestic

Remarks: Computations based on Yellowstone River alluvium.

References:

Reconnaissance groundwater studies, Wheatland, eastern Meagher, and northern Sweet Grass Counties, Montana: MBMG Spec. Pub. 24, 1962.

INDEX MAP NUMBER 58

Tobacco River Valley
Drainage basin 76D

Groundwater in storage, available to wells .... 54,000(b) acre-feet
Perennial recharge .... 9,000(b) acre-feet
Quality—Domestic 1, Irrigation 1

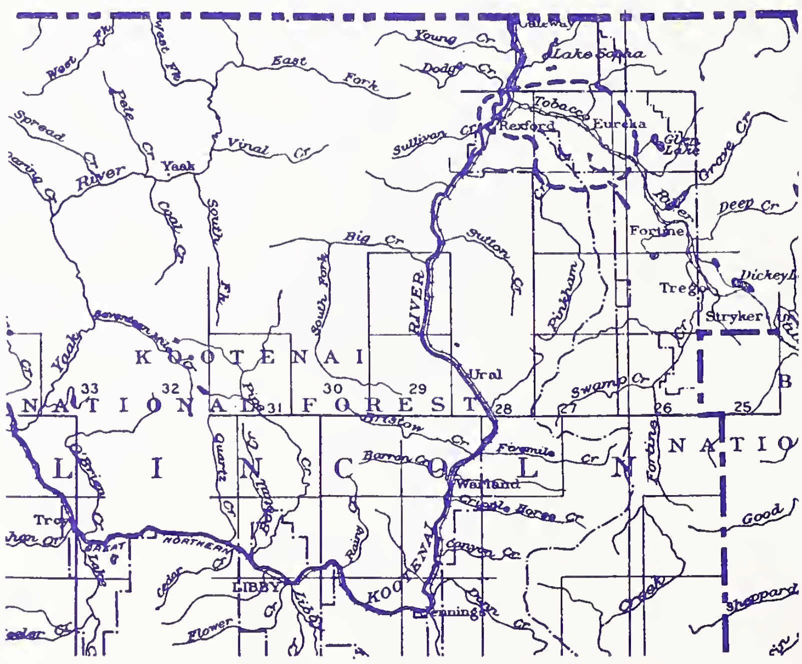


FIG. 41

Map showing general outline of Tobacco Plains alluvial area.

Area of aquifer .... 9,000 acres
Specific yield of aquifer .... .20
Average aquifer thickness (saturated thickness) .... 30 feet
Average thickness permeable alluvium .... 100 feet +
Transmissibility (one well only) .... 2,000 gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER 58

Tobacco River Valley
Drainage basin 76D

Precipitation	14 inches annual average
Well depths	21 - 299 feet
Water table	2 - 133 feet
Well yields (potential 250 - 1000 gpm)	30 - 75 gpm
Specific capacities	15 - 30 gpm/ft.
Number of wells	30+
Temperature of well water (average)	47 °F
Well uses	Chiefly stock and domestic, 3 municipal wells

Remarks: Computations based only on area of Tobacco plains north of Eureka. For the greater area of the project no storage figures have been computed, but stream-flow measurements based on one year of record indicate a high recharge of 110,000 acre-feet per year.

References:

Surficial geology and water resources of the Tobacco and upper Stillwater River Valleys, Lincoln and Flathead Counties, Montana: MBMG Bulletin in preparation.

Mineral and water resources of Montana: USGS and MBMG Spec. Pub. 28, 1963.

INDEX MAP NUMBER 2

Butte, Montana
Drainage basin 76G

Groundwater in storage, available to wells .... 200,000(b) acre-feet
Perennial recharge .... 10,000 acre-feet
Quality—Domestic 1-5, Irrigation 1

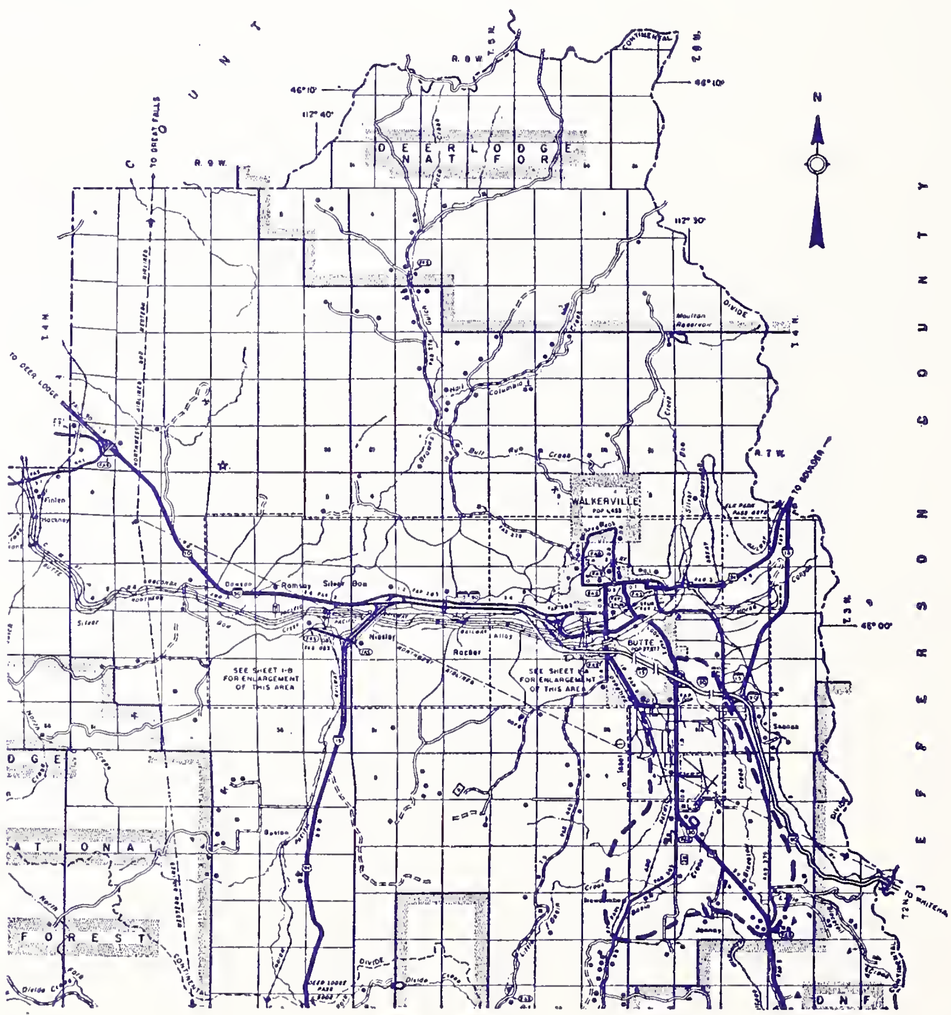


FIG. 42

Outline of alluvial basin in the vicinity of Butte, Montana

Area of aquifer .... 12,000 acres
Specific yield of aquifer .... .15
Average aquifer thickness (saturated thickness) .... 100(b) feet
Average thickness permeable alluvium .... 200(b) feet
Transmissibility .... gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER 2

Butte, Montana
Drainage basin 76G

Precipitation .... 14 inches annual average (17,000 ac-ft/yr.)

Well depths .... 12 - 119 feet

Water table .... 2 - 88 feet

Well yields average 80 gpm .... potential 100 gpm
some small flows

Specific capacities .... 5 gpm/ft.

Number of wells ....

Temperature of well water .... °F

Well uses .... Chiefly stock, domestic, and industrial

Remarks: About 2,000 acres waterlogged
About 400 acres irrigated
Irrigation diversions 1600 ac-ft/yr. +

References:

The water resources of Butte, Montana: USGS Water-Supply Paper 345G, 1914.

INDEX MAP NUMBERS 34, 37, 56

Deer Lodge Valley
Drainage basin 76G

Groundwater in storage, available to wells .... 544,000(b) acre-feet
Perennial recharge .... 50,000 acre-feet
Quality—Domestic 1, Irrigation 1

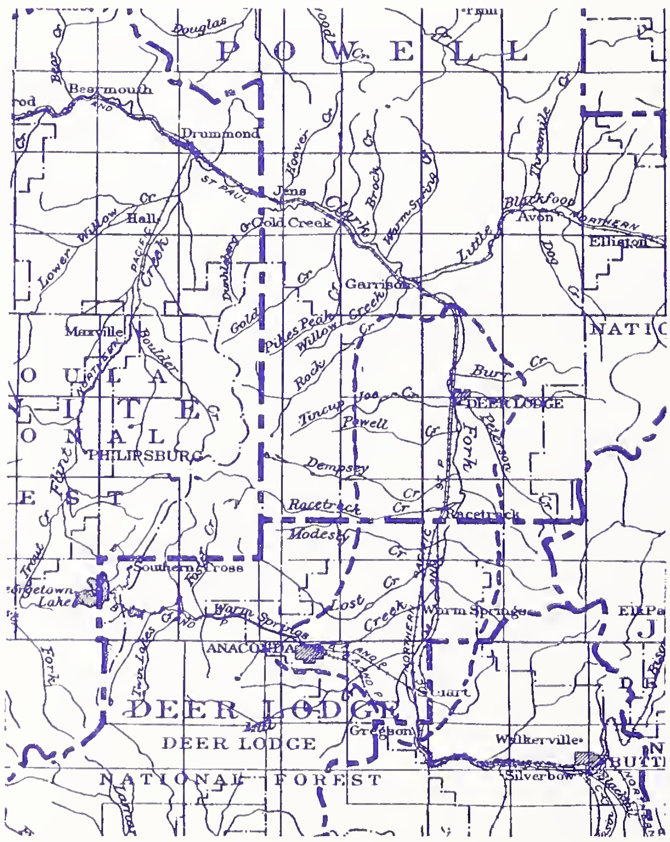


FIG. 43

Generalized outline of Deer Lodge Valley alluvial area.

Area of aquifer .... 64,000(b) acres
Specific yield of aquifer 1
Average aquifer thickness (saturated thickness) .... 85(b) feet
Average thickness permeable alluvium .... 100(b) feet
Transmissibility .... Alluvium 20,000 - 175,000 gpd/ft.
Tertiary deposits 600 - 70,000 gpd/ft.
Alluvium and Tertiary 20,000 - 95,000 gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBERS 34, 37, 56

Deer Lodge Valley
Drainage basin 76G

Precipitation .... 11 inches annual average

Well depths .... 3 - 250 feet

Water table .... from above surface in flowing wells to depths of 150 feet

Well yields .... 10 - 1200 gpm

Specific capacities .... Alluvium 1 - 50 gpm/ft. Tertiary 1 - 40 gpm/ft.
Alluvium and Tertiary 1 - 28 gpm/ft.

Number of wells .... 225+

Temperature of well water .... °F

Well uses—Industrial, municipal, institutional, stock, domestic, and irrigation, totaling 7000 acre-feet annually.

Remarks: Irrigated acres—39,000.

One test hole, reported flow—140 gpm from 1200 feet suitable for public supply—unsuitable for irrigation.

References:

Preliminary report on the geology and groundwater resources of the northern part of the Deer Lodge Valley, Montana: MBMG Bull. 21, 1961.

Preliminary report on the geology and groundwater resources of the southern part of the Deer Lodge Valley, Montana: MBMG Bull. 31, 1962.

Geology and groundwater resources of the Deer Lodge Valley, Montana' USGS Water-Supply Paper 1862, 1968.

INDEX MAP NUMBERS 25, 30

Bitterroot Valley
Drainage basin 76H

Groundwater in storage, available to wells .... 660,000(b) acre-feet
Perennial recharge .... 165,000 acre-feet
Quality—Domestic 1, Irrigation 1

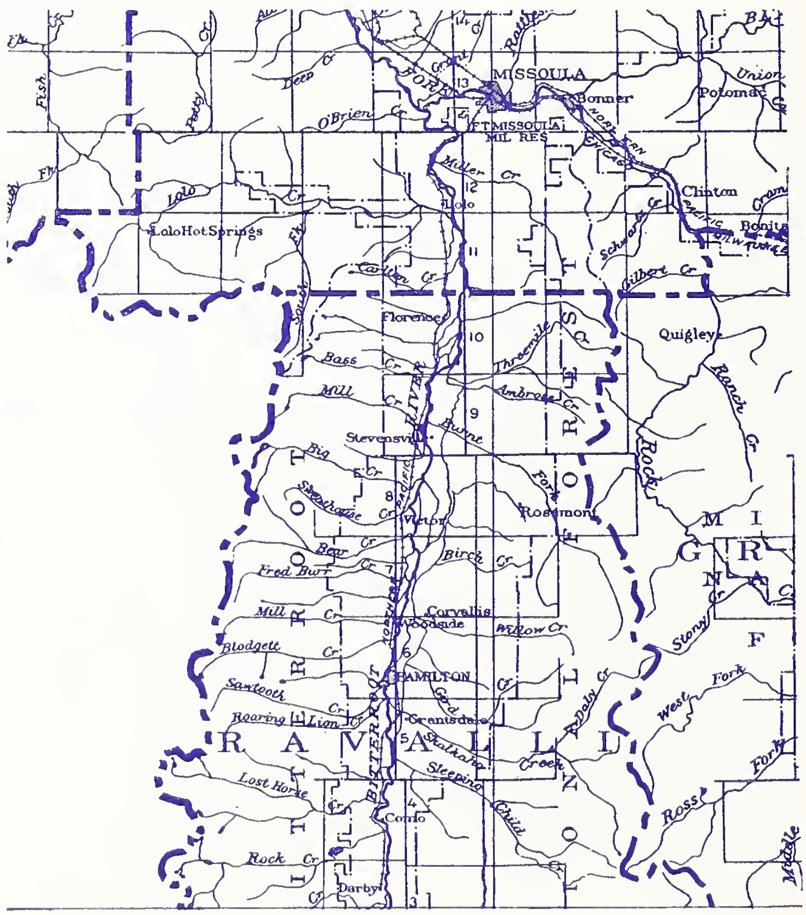


FIG. 44

Bitterroot Valley.

The aquifer is in unconsolidated deposits along the Bitterroot River from the mouth of Sleeping Child Creek north to the Ravalli County line.

Area of aquifer .... 110,000 acres
Specific yield of aquifer .... .15
Average aquifer thickness (saturated thickness) .... 40(b) feet
Average thickness permeable alluvium .... 100 feet +

Transmissibility
Alluvium—T = 20,000 - 280,000 gpd/ft.
Tertiary deposits—T = 2,400 - 3,300 gpd/ft.
Alluvium & Tertiary combined—T = 18,000 gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBERS 25, 30

Bitterroot Valley
Drainage basin 76H

Precipitation	16 inches annual average
Well depths	Flood plain and low terrace deposits, 5 - 47 feet High terraces, 11 - 365 feet
Water table	2 - 22 feet, 5 - 93 feet
Well yields	250 - 1000 gpm
Specific capacities	Alluvium 8 - 230 gpm/ft. Tertiary deposits and alluvium 3 - 9 gpm/ft.
Number of wells	85+
Temperature of well water	°F

Well uses....Chiefly stock and domestic. 20 irrigation wells irrigate 1200 acres

Remarks:

Groundwater movement: 400 feet per year in Tertiary sands
700 feet per year in flood plain alluvium
1000 feet per year through alluvium on west side of river

References:

Progress report on the geology and groundwater resources of the eastern part of the Bitterroot Valley, Montana: MBMG Inf. Circ. 16, 1956.

Preliminary report on the geology and water resources of the Bitterroot Valley, Montana: MBMG Bull. 9, 1959.

Biennial Report, MBMG Spec. Pub. 45, 1968.

INDEX MAP NUMBER 3

Little Bitterroot Valley
Drainage basin 76L

Groundwater in storage, available to wells ....unknown acre-feet
Perennial recharge ....unknown acre-feet
Quality—Domestic 2-3, Irrigation 2-5

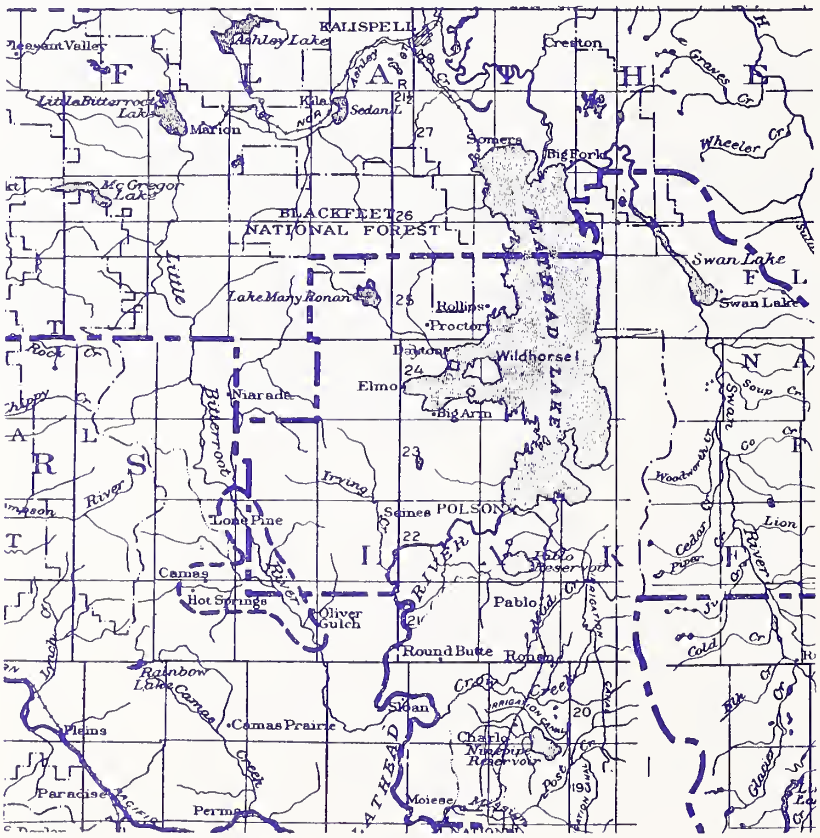


FIG. 45

Little Bitterroot Valley with artesian-well area outlined.

Area of aquifer .... 12,000 acres
Specific yield of aquifer ....
Average aquifer thickness (saturated thickness) ....unknown
Average thickness permeable alluvium ....unknown
Transmissibility .... gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER 3

Little Bitterroot Valley
Drainage basin 76L

Precipitation	12 inches annual average
Well depths	52 - 303 feet
Water table	—100 - +55 feet
Well yields	14 - 385 gpm
Specific capacities	gpm/ft.
Number of wells	40+
Temperature of well water	53 - 120 °F
Well uses	Chiefly irrigation

Remarks: 2000+ acres under irrigation. Considerable loss of water is due to defective valves and casings.

References:

Artesian water for irrigation in Little Bitterroot Valley, Montana: USGS Water-Supply Paper 400B, 1916.

INDEX MAP NUMBER 12

Camas Prairie Valley
Drainage basin 76L

Groundwater in storage, available to wells .... 90,000(b) acre-feet
Perennial recharge .... 10,000(b) acre-feet
Quality—Domestic and irrigation, 1

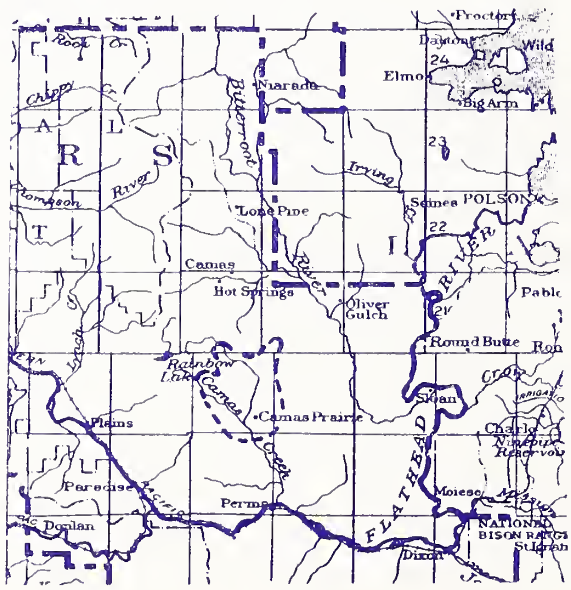


FIG. 46

Camas Prairie Valley, with alluvial area outlined.

Area of aquifer .... 15,000(b) acres
Specific yield of aquifer .... .15(b)
Average aquifer thickness (saturated thickness) .... 40(b) feet
Average thickness permeable alluvium .... 60(b) feet
Transmissibility .... gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBER 12

Camas Prairie Valley
Drainage basin 76L

Precipitation	16 inches annual average
Well depths	10 - 75 feet
Water table	5 - 70 feet
Well yields	200 - 500 gpm
Specific capacities	gpm/ft.
Number of wells	
Temperature of well water	°F
Well uses	Stock and domestic

Remarks: About 300 acres waterlogged.
Hot springs in sec. 33, T. 20 N., R. 24 W.
Flow not measured, temperature 110° - 114° F.

References:

Shallow wells as a source of irrigation water in Frenchtown and Camas Prairie Valleys, Montana: MBMG Misc. Contr. 5, 1933.

INDEX MAP NUMBERS 49, 53, 20

Kalispell Valley perched aquifers
Drainage basin 76 L J

Groundwater in storage, available to wells in dune sand....180,000 acre-feet
Perennial recharge (mostly from precipitation)
Dune sand .... 10,000 acre-feet Pothole lake area.. 11,000 acre-feet
Quality—Domestic 1-5 (some high nitrates), Irrigation 1

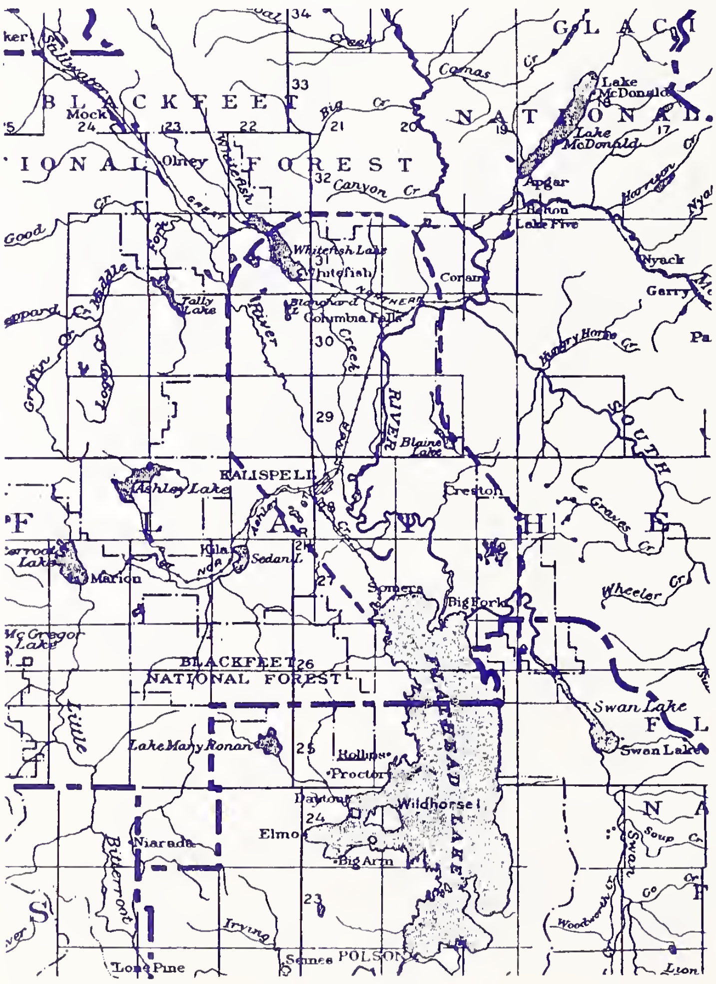


FIG. 47

General outline of Kalispell Valley report area.

Area of aquifer in dune sand .... 67,000 acres
Specific yield of aquifer .... .10
Average aquifer thickness (saturated thickness) .... 27 feet
Average thickness permeable alluvium .... 40 feet
Transmissibility (in outwash sands and gravels) .... 570,000 gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBERS 49, 53, 20

Kalispell Valley perched aquifers
Drainage basin 76 L J

Precipitation	15 inches annual average
Well depths (dune sand)	6 - 58 feet
(outwash sand)	22 - 94 feet
Water table (dune sand)	3 - 52 feet
Average of 8 wells (outwash sand)	38 feet
Well yields	Up to 10 gpm sustained yield (greater potential) 70 - 200 gpm from large diameter wells (48″ diameter)
Specific capacities	gpm/ft.
Number of wells	109+
Temperature of well water	47 - 52 °F
Well uses	393 ac-ft/yr.—used for stock, domestic, and irrigation

Remarks: Perched aquifers include dune and lacustrine sands, outwash sand and gravel, and glacial drift sand and gravel in the pothole lake area. These deposits are widespread in the Kalispell Valley. Losses from dune sand, 335 ac-ft/yr., due to discharge by springs.

Infiltration of precipitation 16% in dune sand.

References:

Geology and groundwater resources of the Kalispell Valley, Montana: MBMG Bull. 68, 1968.

Basic water data report no. 3, Kalispell Valley, Montana: MBMG Bull. 53, 1966.

An investigation of the groundwater of the area north of Flathead Lake, Montana: Student report submitted to Montana College of Mineral Science and Technology, 1951.

INDEX MAP NUMBERS 49, 53, 20

Kalispell Valley shallow artesian aquifer
Drainage basin 76 L J

Groundwater in storage ....unknown acre-feet
Perennial recharge (in excess of capacity) ....acre-feet
Quality—Domestic 1, Irrigation 1

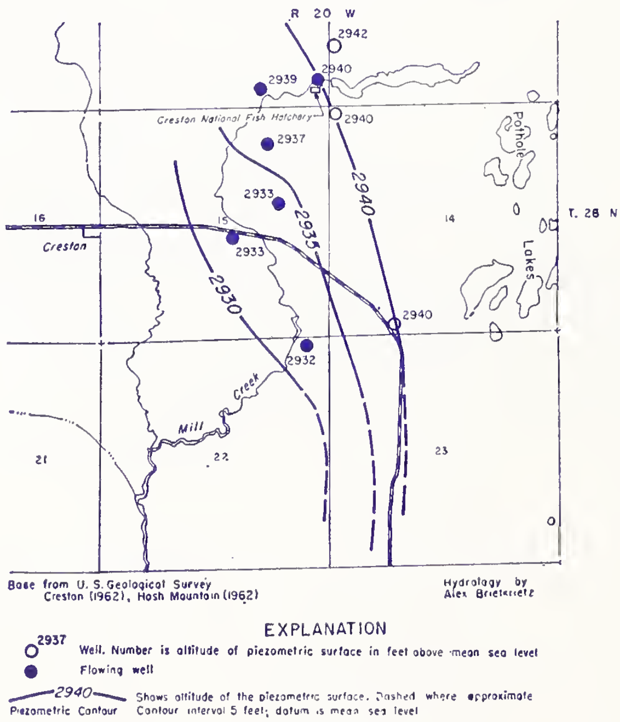


FIG. 48

Area of shallow artesian aquifer in the Creston area.

Area of aquifer .... 3,800 acres
Specific yield of aquifer
Average aquifer thickness 60 feet + near Creston (T. 28 N., R. 20 W.)
Transmissibility .... gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBERS 49, 53, 20

Kalispell Valley shallow artesian aquifer
Drainage basin 76 L J

Precipitation	15 inches annual average
Well depths	103 - 176 feet
Water table	+19 - —21 feet
Well yields	3 - 10 gpm flows
Specific capacities	.3 - .5 gpm/ft.
Number of wells	21+
Temperature of well water (one well only)	50 °F
Well uses	374 ac-ft/yr. used for stock, domestic, and irrigation

Remarks: Pothole lake area provides recharge to shallow artesian aquifer. Another shallow artesian aquifer is in T. 29 N., R. 20 W., in sections 4, 5, 9, and 16.

References:

Geology and groundwater resources of the Kalispell Valley, Montana: MBMG Bull. 68, 1968.

Basic water data report no. 3, Kalispell Valley, Montana: MBMG Bull. 53, 1966.

An investigation of the groundwater of the area north of Flathead Lake, Montana: Student report submitted to Montana College of Mineral Science and Technology, 1951.

INDEX MAP NUMBERS 49, 53, 20

Kalispell Valley, deep artesian aquifer
Drainage basin 76 L J

Groundwater in storage.. unknown acre-feet
Perennial recharge .... 30,000 acre-feet
Quality—Domestic 1-5 (some high in iron and fluorides), Irrigation 1

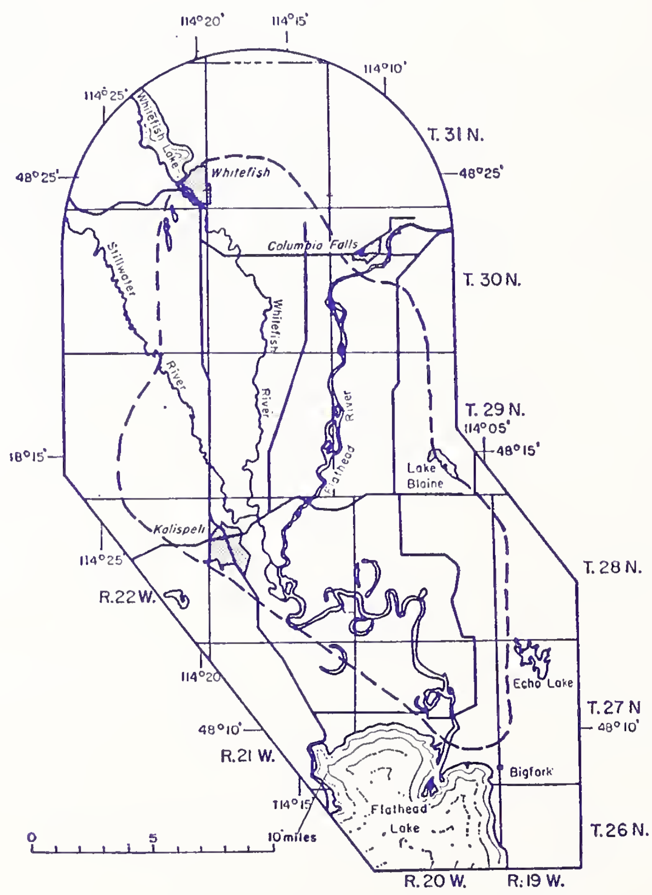


FIG. 49

Map showing project area with approximate area of deep artesian aquifer enclosed by dashed line.

Area of aquifer .... 146,000 acres
Specific yield of aquifer ....
Aquifer thickness known from only one well .... 364 feet
Transmissibility .... 360 - 3800 gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBERS 49, 53, 20

Kalispell Valley, deep artesian aquifer
Drainage basin 76 L J

Precipitation .... 15 inches annual average

Well depths .... 109 - 480 feet

Water table .... +36 to —174 feet

Well yields, flows 1 - 225 gpm .... potential 1500 gpm

Specific capacities .... .3 to 1.9 gpm/ft.

Number of wells .... 213+

Temperature of well water, 48° - 66° F........ Average 50 °F

Well uses—6200 ac-ft/yr. for domestic, stock, municipal, industrial, and irrigation use.

Remarks: Coefficient of storage—$S = 8.7 \times 10^{-4}$ (estimate)

References:

Geology and groundwater resources of the Kalispell Valley, Montana: MBMG Bull. 68, 1968.

Basic water data report no. 3, Kalispell Valley, Montana: MBMG Bull. 53, 1966.

An investigation of the groundwater of the area north of Flathead Lake, Montana: Student report submitted to Montana College of Mineral Science and Technology, 1951.

INDEX MAP NUMBERS 49, 53, 20

Kalispell Valley, alluvial gravel aquifer
Drainage basin 76 L J

Groundwater in storage, available to wells .... 170,000 acre-feet
Perennial recharge .... 21,000 acre-feet
Quality—Domestic 1, Irrigation 1

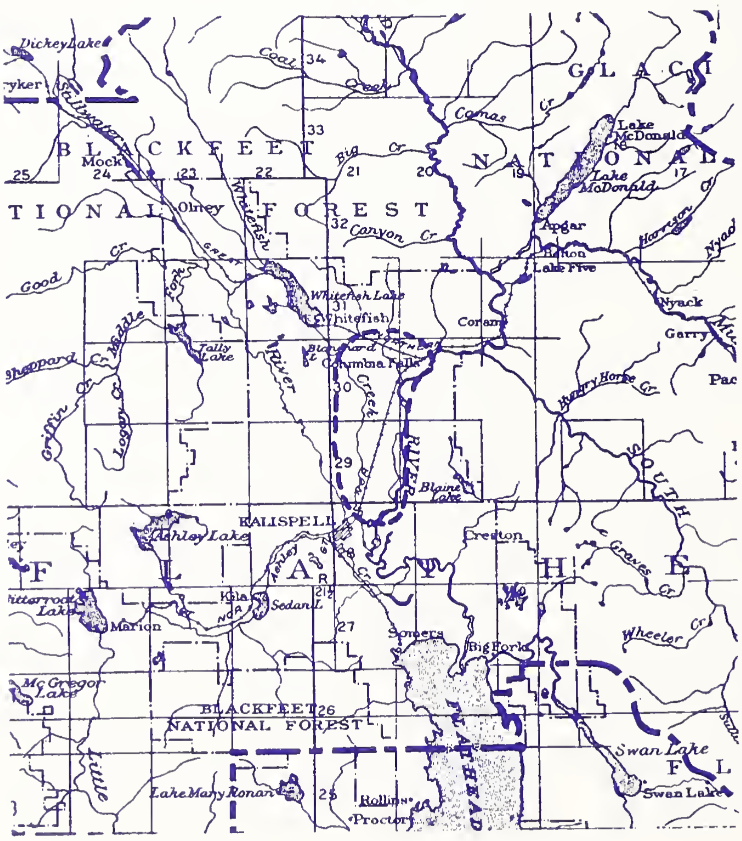


FIG. 50

Map showing general area of alluvial gravel aquifer, enclosed by dashed line.

Area of aquifer .... 34,800 acres
Specific yield of aquifer .... .20
Average aquifer thickness (saturated thickness) .... 25 feet
Average thickness permeable alluvium .... 28 feet
Transmissibility .... (average) 1,100,000 gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBERS 49, 53, 20

Kalispell Valley, alluvial gravel aquifer
Drainage basin 76 L J

Precipitation .... 15 inches annual average

Well depths .... 18 feet +

Water table .... 12 feet +

Well yields, 250 - 480 gpm .... potential more than 1500 gpm

Specific capacities .... 260 - 370 gpm/ft.

Number of wells .... 82+

Temperature of well water .... °F

Well uses, 10,500 ac-ft/yr. for domestic, stock, municipal, irrigation, and industrial uses.

Remarks: 1680 ac-ft/yr. from Kalispell municipal spring. This alluvial gravel aquifer has the greatest development potential in this area.

References:

Geology and groundwater resources of the Kalispell Valley, Montana: MBMG Bull. 68, 1968.

Basic water data report no. 3, Kalispell Valley, Montana: MBMG Bull. 53, 1966.

An investigation of the groundwater of the area north of Flathead Lake, Montana: Student report submitted to Montana College of Mineral Science and Technology, 1951.

INDEX MAP NUMBERS 49, 53, 20

Kalispell Valley alluvial sand aquifer
Drainage basin 76 L J

Groundwater in storage, available to wells	50,000 acre-feet
Perennial recharge	4,000 acre-feet

Quality—Domestic 3-5 (some high iron, nitrate), Irrigation 1

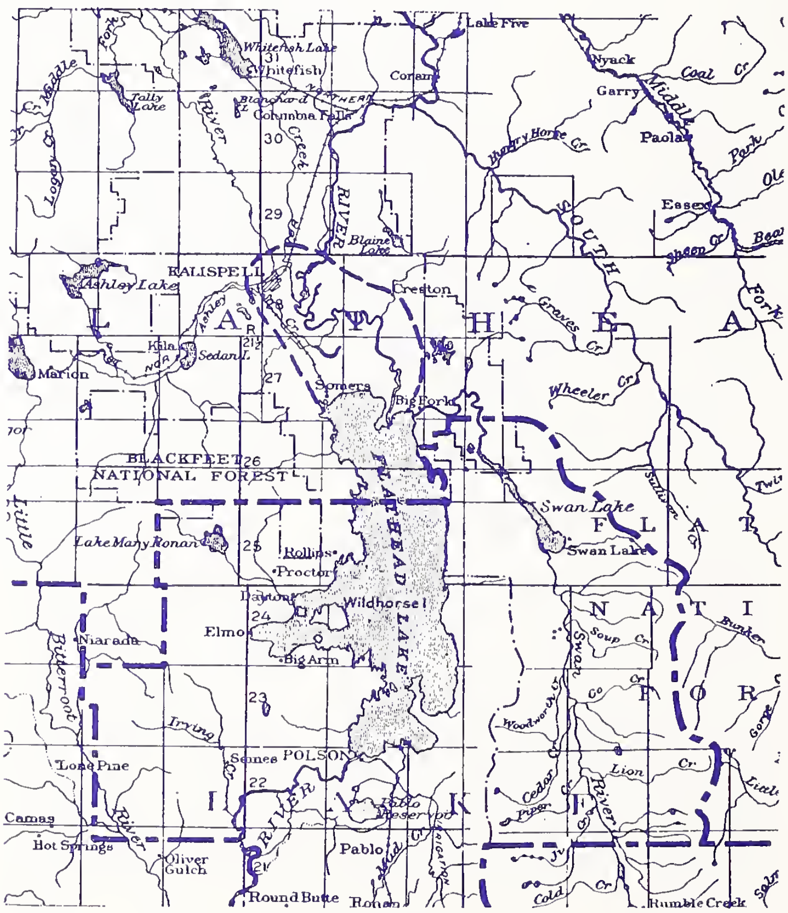


FIG. 51

Map showing area of alluvial sand aquifer, enclosed by dashed line.

Area of aquifer	18,000 acres
Specific yield of aquifer	.1
Average aquifer thickness (saturated thickness)	28 feet
Average thickness permeable alluvium	35 feet
Transmissibility	7,500 gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBERS 49, 53, 20

Kalispell Valley alluvial sand aquifer
Drainage basin 76 L J

Precipitation	15 inches annual average
Well depths	9 - 35 feet
Water table	7 - 22 feet
Well yields	Low
Specific capacities	gpm/ft.
Number of wells	46+
Temperature of well water (one only)	48 °F
Well uses	Stock and domestic—about 50 ac-ft/yr.

Remarks: Not used for irrigation because of low well yields. Losses due to evapotranspiration from 1,700 acre swamp—3400 ac-ft/yr.

References:

Geology and groundwater resources of the Kalispell Valley, Montana: MBMG Bull. 68, 1968.

Basic water data report no. 3, Kalispell Valley, Montana: MBMG Bull. 53, 1966.

An investigation of the groundwater of the area north of Flathead Lake, Montana: Student report submitted to Montana College of Mineral Science and Technology, 1951.

INDEX MAP NUMBERS 40, 42, 12

Missoula Basin
Drainage basin 76M

Groundwater in storage, available to wells	1,750,000 acre-feet
Perennial recharge	50,000 acre-feet

Quality—Domestic 1, Industrial 1, Irrigation 1 (with few exceptions)

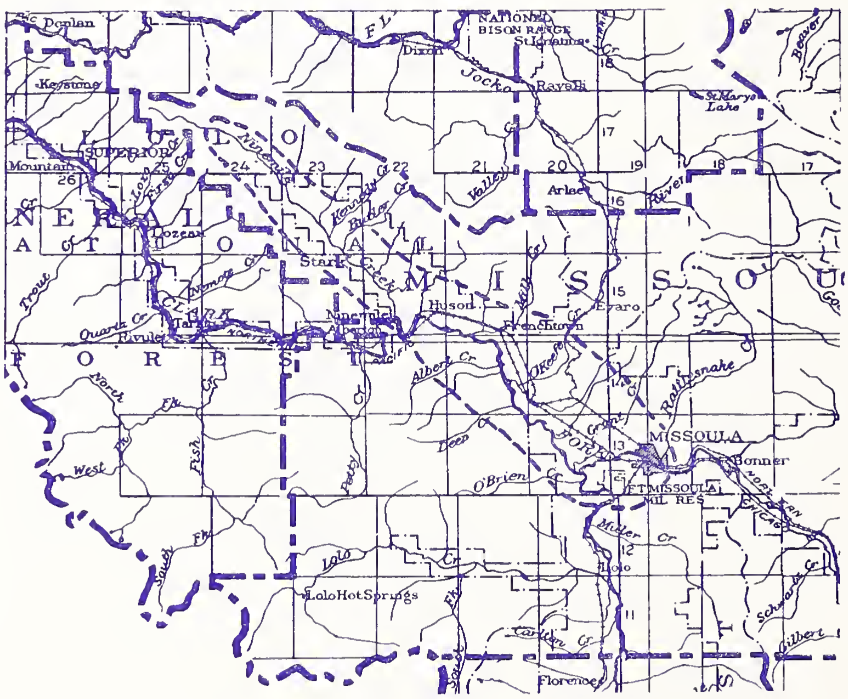


FIG. 52

General outline of the Missoula Basin.

The aquifer is in alluvium along the Clark Fork and Nine Mile Valleys.

Area of aquifer	77,000 acres
Specific yield of aquifer	.1
Average aquifer thickness (saturated thickness)	200 feet
Average thickness permeable alluvium	300 feet
Transmissibility	85,000 - 1,800,000 gpd/ft.

SPECIFIC INFORMATION
INDEX MAP NUMBERS 40, 42, 12

Missoula Basin
Drainage basin 76M

Precipitation .... 12 inches annual average

Well depths .... Most less than 175 feet, some as deep as 550 feet

Water table .... about 50′ to 290′

Well yields .... to 5000 gpm

Specific capacities .... 150 - 266 gpm/ft.

Number of wells .... 276+

Temperature of well water .... °F

Well uses..Chiefly domestic and stock. Several irrigation and industrial wells.

Remarks: 24,000 acre-feet pumped in 1963. Storage figure is referred to the upper 200 feet of the aquifer.

References:

Geology and groundwater resources of the Missoula Basin, Montana: MBMG Bull. 47, 1965.

Basic water data report no. 1, Missoula Valley, Montana: MBMG Bull. 37, 1964.

Shallow wells as a source of irrigation water in Frenchtown and Camas Prairie Valleys, Montana: MBMG Misc. Contr. 5, 1933.

TABLE 1

GROUNDWATER DATA FOR TH

Area summarized Publication or other sources	Area of aquifer Permeable thickness Saturated thickness Specific yield	Precipitation Available storage Perennial recharge
Musselshell River Valley. Reconnaissance groundwater studies in Wheatland, eastern Meagher, and northern Sweet Grass Counties, Montana: MBMG Spec. Publ. 24, 1962.	27,000 acres 25′ 15′ .1	12″ 40,000 ac-ft 6,000 ac-ft
Golden Valley and Musselshell Counties (Musselshell Valley). Groundwater in Musselshell and Golden Valley Counties, Montana: USGS Water-Supply Paper 518, 1924.	12,000 acres 30′ 15′ .15	12″ 27,000 ac-ft 4,000 ac-ft
Musselshell County (Musselshell Valley). Groundwater in Musselshell and Golden Valley Counties, Montana: USGS Water-Supply Paper 518, 1924.	22,000 acres 30′ 15′ .15	12″ 50,000 ac-ft 8,000 ac-ft
Big Sandy-Laredo area. Geology and groundwater resources of the lower Marias irrigation project, Montana: USGS Water-Supply Paper 1460-B, 1957.	44,000 acres 100′± 60′ .15	12″ 396,000 ac-ft 20,000 ac-ft
Northern Blaine County (Flaxville Formation only). Geology and groundwater resources of northern Blaine County, Montana: MBMG Bulletin 19, 1960.	100,000 acres 75′ 15′ .20	12″ 300,000 ac-ft 5,000 ac-ft
Milk River (Blaine and Phillips Counties). Geology and hydrology of the Fort Belknap Indian Reservation, Montana: USGS Water-Supply Paper 1576F, 1965.	38,000 acres 30′ 10′ .15	12″ 57,000 ac-ft 3,500 ac-ft
Missouri River Valley (northeast Montana). Geology and groundwater resources of the Missouri River Valley in northeastern Montana: USGS Water-Supply Paper 1263, 1955.	157,000 acres 65′± 15′ .15	12″ 345,000 ac-ft 70,000 ac-ft
Red Rock River Valley. Water power and irrigation in the Jefferson River Basin, Montana: USGS Water-Supply Paper 580B, 1926.	200,000 acres 30′ 10′ .10	14″ 200,000 ac-ft 40,000 ac-ft
Beaverhead River Valley. Water power and irrigation in the Jefferson River Basin, Montana: USGS Water-Supply Paper 580B, 1926.	78,000 acres 100′± 20′ .15	12″ 234,000 ac-ft 40,000 ac-ft
Ruby River Valley. Water power and irrigation in the Jefferson River Basin, Montana: USGS Water-Supply Paper 580B, 1926.	34,500 acres 25′ 10′ .10	12″ 35,000 ac-ft 6,000 ac-ft

NCONSOLIDATED AQUIFERS

No. of wells Depths Yields	Quality Temperature Water table	Pump test data Geologic source Uses	Remarks Index map number River basin code no.
30+ 18'-140' Small to large	D satisfactory ——— 4'-120'	——— Alluvium S, D	35 40A
38+ 9'-60' Average 10-20 gpm up to 500 gpm	D 1-5, Irr. 1-5 49° 6'-22'	——— Alluvium S, D	4, 27 40A
52+ 10'-39' Average 5-20 gpm Up to 500 gpm	D 1-5, Irr. 1-5 49° 6'-27'	——— Alluvium S, D	4, 27 40C
207+ 11'-400' 15-50 gpm Potential 250 gpm +	D 1-5, Irr. 1-5 ——— 3'-154'	Sp. Cap. (1-only) 25 gpm/ft. Alluvium S, D	28 40H
20+ 39'-49' Up to 1200 gpm	D 1-3, Irr. 1 46°-49° F 30'	——— Flaxville Fm. (Sands and gravels) S, D, Irr.	Infiltration of precipitation estimated at 5% 33 40J
37+ 7'-83' Small to large	D 3-5, Irr. 5 ——— 3'-16'	——— Trans. 66,000 gpd/ft. (in pre-glacial channel gravels) S, D	45 40J
200+ 15'-210' 18-650 gpm	D 1-5, Irr. 5 ——— 5'-70'	Sp. Cap. 20-91 gpm/ft. Alluvium S, D	18, 23 40S
——— 17'-499' 4-1200 gpm	D 1, Irr. 1 ——— 3'-235'	Specific capacities .2 to 3.0 gpm/ft. Alluvium S, D	55A 41A
——— 15'-160' 5-1800 gpm (most 5-20)	D 1, Irr. 1 ——— 3'-124'	Specific capacities up to 300 gpm/ft. Alluvium S, D	55B, 60 41B
——— 33'-155' 10-30 gpm	D 1, Irr. 1 ——— 4'-110'	Specific capacities .6 to 3.0 gpm/ft. Alluvium S, D	55C 41C

TABLE 1—(Continued)

GROUNDWATER DATA FOR THE

Area summarized Publication or other sources	Area of aquifer Permeable thickness Saturated thickness Specific yield	Precipitation Available storage Perennial recharge
Big Hole Basin. Physiography and groundwater supply in the Big Hole Basin, Montana: MBMG Memoir 12, 1934.	248,000 acres 160'± 30' .15	12" 1,100,000 ac-ft 180,000 ac-ft
Elk Park Valley (Jefferson County). Montana Highway Dept. test hole logs, Elk Park, Montana topographic map 15' series, 1954.	9,000 acres 45' 30' .15	14" 40,000 ac-ft 6,000 ac-ft
Boulder Valley. Letter dated Dec. 19, 1968, Montana Water Resources Board, from Mr. M. K. Botz, Montana Bureau of Mines & Geology.	3,200 acres 100' 80' .20	12" 50,000 ac-ft 8,000 ac-ft
Boulder River Valley. Water power and irrigation in the Jefferson River Basin, Montana: USGS Water-Supply Paper 580B, 1926.	16,000 acres 20' 10' .10	12" 16,000 ac-ft 3,000 ac-ft
Madison River Valley. Water power and irrigation in the Madison River Basin, Montana: USGS Water-Supply Paper 560A, 1925.	50,000 acres 100'± 35' .15	16" 260,000 ac-ft 40,000 ac-ft
Jefferson River Valley. Water power and irrigation in the Jefferson River Basin, Montana: USGS Water-Supply Paper, 580B, 1926.	45,000 acres 50' 25' .10	12" 110,000 ac-ft 18,000 ac-ft
Gallatin Valley. Geology and groundwater resources of the Gallatin Valley, Gallatin County, Montana: USGS Water-Supply Paper 1482, 1960.	107,000 acres 125' 100' .15	18" 1,600,000 ac-ft 240,000 ac-ft
Townsend Valley. Geology and groundwater resources of the Townsend Valley, Montana: USGS Water-Supply Paper 539, 1925.	37,000 acres 100'± 20' .15	12" 110,000 ac-ft 16,000 ac-ft
Helena Valley. Geology and groundwater resources of the Helena Valley, Montana: USGS Circ. 83, 1951.	20,000 acres 100± 50' .15	12" 150,000 ac-ft 18,000 ac-ft

NCONSOLIDATED AQUIFERS

No. of wells Depths Yields	Quality Temperature Water table	Pump test data Geologic source Uses	Remarks Index map number River basin code no.
——— 20'-320' alluvium 100'-200' terraces 250-1000 gpm	D 1, Irr. 1 ——— 5'-23'	——— Alluvium Terraces S, D	17, 55D 41D
(Few) 17'-66' ———	D 1, Irr. 1 ——— 2'-18'	Alluvium	——— 41E
5+ 72'-90' 80-240 gpm	D 1, Irr. 1 ——— 20' (average)	Sp. Cap. 12-60 gpm/ft. Trans. (Av.) 144,000 gpd/ft. Alluvium S, D, Mun.	——— 41E
——— 12'-260' 8-50 gpm Potential 250 gpm	D 1, Irr. 1 ——— 6'-180'	Specific capacities 12-60 gpm/ft. Alluvium S, D, Mun., Inst.	55E 41E
——— 41'-620' Most 12-60 gpm, 1000 gpm (potential in middle valley)	D 1, Irr. 1 ——— 11'-?	Specific capacities .5 to 8 gpm/ft. Alluvium S, D	54 41F
——— 38'-169' 10-30 gpm Potential 250 gpm	D 1, Irr. 1 ——— 4'-56'	Alluvium	55F 41G
1100+ 10'-105' 16-2000 gpm	D 1, Irr. 1 44°59° F 5'-25'	Specific capacities 98 gpm/ft. Trans. 200,000 gpd/ft. Alluvium S, D	31 41H
530+ 20'-200' 8-10 gpm	D 1-5, Irr. 2-3 1'-171'	——— Alluvium S, D	7000 acres waterlogged 5, 24 41-I
120+ 8'-408' 150-300 gpm Potential 1000 gpm Flows 25-125 gpm	D 1, Irr. 1-2 ——— 1'-67'	——— Alluvium (Valley fill)	21 41-I

TABLE 1—(Continued)

GROUNDWATER DATA FOR THE

Area summarized Publication or other sources	Area of aquifer Permeable thickness Saturated thickness Specific yield	Precipitation Available storage Perennial recharge
White Sulphur Springs area. Reconnaissance groundwater and geological studies, western Meagher County, Montana: MBMG Spec. Publ. 35, 1965.	10,000 acres 30′ 20′ .20	18″ 40,000 ac-ft 8,000 ac-ft
Cascade-Ulm area (Smith River Valley). Geology and groundwater resources of the Cascade-Ulm area, Montana: MBMG Bull. 52, 1966.	6,000 acres 50′ 25′ .15	15″ 22,000 ac-ft 3,000 ac-ft
Lower Sun River. Geology and water resources of the Great Falls region, Montana: USGS Water-Supply Paper 221, 1909.	122,000 acres 35′ 10′ .15	14″ 180,000 ac-ft 30,000 ac-ft
Lower Teton River. Geology and water resources of the Great Falls region, Montana: USGS Water-Supply Paper 221, 1909.	51,000 acres 30′ 10′ .15	12″ 75,000 ac-ft 12,000 ac-ft
Cascade-Ulm area (Missouri River Valley). Geology and groundwater resources of the Cascade-Ulm area, Montana: MBMG Bull. 52, 1966.	36,000 acres 70′ 25′ .15	15″ 135,000 ac-ft 20,000 ac-ft
Judith Basin. Groundwater resources of Judith Basin, Montana: MBMG Memoir 7, 1932.	Not computed	12″
Yellowstone Valley. Groundwater resources of the Yellowstone Valley between Miles City and Glendive, Montana: USGS Circ. 93, 1951.	24,000 acres 35′± 8′ .15	13″ 28,000 ac-ft 8,000 ac-ft
Treasure County (Yellowstone Valley). Groundwater in Yellowstone and Treasure Counties, Montana: USGS Water-Supply Paper 599, 1929.	25,000 acres 40′ 9′ .15	12″ 33,000 ac-ft 5,000 ac-ft
Rosebud County (Yellowstone Valley). Geology and groundwater resources of central and southern Rosebud County, Montana: USGS Water-Supply Paper 600, 1929.	22,000 acres 30′ 10′ .15	14″ 33,000 ac-ft 6,000 ac-ft

'NCONSOLIDATED AQUIFERS

No. of wells Depths Yields	Quality Temperature Water table	Pump test data Geologic source Uses	Remarks Index map number River basin code no.
90+ 12'-300' Up to 1850 gpm	D 1, Irr. 1-3 ——— 5'-100'	——— Alluvium S, D, Irr.	44 41J
16+ 11'-205' 4-46 gpm	D 1, Irr. 1 ——— 2'-190'	——— Alluvium S, D	48, 39 41J
——— 12'-187' 5-60 gpm Potential 250-1000 gpm	D 1, Irr. 1 ——— 5'-60'	——— Alluvium S, D	1 41K
——— 10'-135' 5-70 gpm	D 1-3, Irr. 1-3 ——— 6-40 gpm	——— Alluvium S, D	1 41-O
47+ 11'-200' 1-70 gpm Flows up to 30 gpm	D 1, Irr. 1 ——— 4'-55'	——— Alluvium S, D, Irr.	48, 39 41QJ
67+ 5'-40' in alluvium 9'-128' terraces 5-25 gpm alluvium Up to 15 gpm in terraces	D 1-5, Irr. 3-5 43°-73° F (terraces) 43°-57° F (alluvium) 3'-36' alluvium 2'-85' terraces	——— Alluvium Terraces	10, 38, 46, 47 41R, 41S
122+ 10'-40' alluvium 10'-100' terraces Small to moderate Potential 250 gpm + near Miles City	D 1-3, Irr. 1-5 ——— 2'-18'	——— Alluvium Terraces	22, 13 42K
16+ 6'-60' Small to moderate	D 1-5, Irr. 1-5 ——— 4'-50'	——— Alluvium S, D	6 42KJ
43+ 8'-70' 5 gpm Potential to 100 gpm	D 3-5, Irr. 1-5 in alluvium D 1, Irr. 1 in terraces 3'-34'	——— Alluvium S, D	7 42KJ

TABLE 1—(Continued)

GROUNDWATER DATA FOR THI

Area summarized Publication or other sources	Area of aquifer Permeable thickness Saturated thickness Specific yield	Precipitation Available storage Perennial recharge
Yellowstone Valley—Terry to Glendive. Groundwater factors affecting drainage in the First Division, Buffalo Rapids irrigation project, Prairie and Dawson Counties, Montana: USGS Water-Supply Paper 1424, 1958.	26,000 acres 25′ 10′ .15	14″ 39,000 ac-ft 11,000 ac-ft
Yellowstone Valley (lower). Geology and groundwater resources of the Yellowstone River valley between Glendive and Sidney, Montana: USGS Water-Supply Paper 1355, 1956.	76,000 acres 40′ 12′ .15	14″ 132,000 ac-ft 22,000 ac-ft
Shields River Valley. Reconnaissance groundwater studies, northern Park County, Montana: MBMG Spec. Publ. 26, 1962.	2,000 acres 52′ 20′ .15	14″ 6,000 ac-ft 1,000 ac-ft
Yellowstone River Valley (in Park County). Reconnaissance groundwater studies, northern Park County, Montana: MBMG Spec. Publ. 26, 1962.	10,000 acres 52′ 20′ .15	14″ 30,000 ac-ft 5,000 ac-ft
Yellowstone River Valley (in Sweet Grass County). Reconnaissance groundwater studies in Wheatland, eastern Meagher, and northern Sweet Grass Counties, Montana: MBMG Spec. Publ. 24, 1962.	18,000 acres 30′ 15′ .15	14″ 40,000 ac-ft 6,800 ac-ft
Clarks Fork and Rock Creek Valleys. Groundwater inventory, Carbon County, Montana: Montana Water Resources Board (in preparation), 1969.	73,000 acres 30′ 16′ .10	14″ 118,000 ac-ft 36,000 ac-ft
Little Bighorn Valley (lower). Geology and groundwater resources of the lower Little Bighorn River Valley, Big Horn County, Montana: USGS Water-Supply Paper 1487, 1960.	14,000 acres 16′ 11′ .15	12″ 23,000 ac-ft 7,000 ac-ft
Lower Bighorn Valley. Geology and groundwater resources of the Lower Bighorn Valley, Montana: USGS Water-Supply Paper 1876, 1968.	60,000 acres 30′ 10′ .15	12″ 90,000 ac-ft 15,000 ac-ft
Yellowstone and Treasure Counties (Yellowstone Valley). Groundwater in Yellowstone and Treasure Counties, Montana: USGS Water-Supply Paper 599, 1929.	125,000 acres 40′ 9′ .15	12″ 167,000 ac-ft 28,000 ac-ft

UNCONSOLIDATED AQUIFERS

No. of wells Depths Yields	Quality Temperature Water table	Pump test data Geologic source Uses	Remarks Index map number River basin code no.
325+ 6′-135′ Adequate to abundant 250-466 gpm near Terry	D 3-5, Irr. 3-5 —— 1′-35′	—— Alluvium Terraces S, D	29, 8, 22 42M
314+ 19′-81′ Small to moderate Potential 250 gpm +	D 1-5, Irr. 1-5 —— 7′-53′	—— Alluvium S, D, Mun.	26 42M
100+ 6′-48′ 12-640 gpm	D satisfactory —— 2′-20′	—— Alluvium S, D	Storage and recharge computations are for Shields River alluvium only 36 43A
25+ 8′-52′ 19-900 gpm	D satisfactory —— 6′-23′	—— Alluvium S, D, Mun.	Storage and recharge computations are for Yellowstone River alluvium only. 36 43B
36+ 10′-60′ Small to moderate	D satisfactory —— 6′-12′	—— Alluvium S, D	35 43B
600 10′-74′ 10-300 gpm	D 1-3, Irr. 1-3 —— 5′-43′	Specific Capacities (average) 10 gpm/ft. Alluvium S, D	43D
200+ 8′-40′ Up to 100 gpm Potential to 300 gpm	D 1-5, Irr. 1-5 —— 1′-30′	—— Alluvium S, D	32 43-O
270+ 5′-55′ Up to 100 gpm Some flows	D 1-5, Irr. 1-2 39°-68° F 1′-30′	Sp. Cap. 17 gpm/ft. (in terrace gravels) Trans. 2,000-55,000 gpd/ft. Alluvium, terraces S, D	52 43P
31+ 6′-60′ 10-100 gpm	D 1-5, Irr. 1-5 —— 4′-50′	—— Alluvium S, D	6, 59 43Q

TABLE 1—(Continued)

GROUNDWATER DATA FOR THE

Area summarized Publication or other sources	Area of aquifer Permeable thickness Saturated thickness Specific yield	Precipitation Available storage Perennial recharge
Yellowstone River Valley (in Sweet Grass County). Reconnaissance groundwater studies in Wheatland, eastern Meagher, and northern Sweet Grass Counties, Montana: MBMG Spec. Publ. 24, 1962.	3,000 acres 30' 15' .15	14" 7,000 ac-ft 1,200 ac-ft
Tobacco Plains. Surficial geology and water resources of the Tobacco and upper Stillwater River Valleys, Lincoln and Flathead Counties, Montana: MBMG Bulletin in preparation.	9,000 acres 100'± 30' .20	20" 54,000 ac-ft 9,000 ac-ft
Butte and vicinity. The water resources of Butte, Montana: USGS Water-Supply Paper 345G, 1914.	12,000 acres 200' 100' .15	14" 200,000 ac-ft 10,000 ac-ft
Deer Lodge Valley. Geology and groundwater resources of the Deer Lodge Valley, Montana: USGS Water-Supply Paper 1862, 1968.	64,000 acres 100' 85' .1	11" 544,000 ac-ft 50,000 ac-ft
Bitterroot Valley. Progress report on the geology and groundwater resources of the eastern part of the Bitterroot Valley, Montana: MBMG Inf. Circ. 16, 1956.	110,000 acres 100'± 40' .15	16" 660,000 ac-ft 165,000 ac-ft
Little Bitterroot Valley. Artesian water for irrigation in Little Bitterroot Valley, Montana: USGS Water-Supply Paper 400B, 1916.	12,000 acres ——— ——— ———	12" ——— ———
Camas Prairie. Shallow wells as a source of irrigation water in Frenchtown and Camas Prairie Valleys, Montana: MBMG Misc. Contr. 5, 1933.	15,000 acres 60'± 40' .15	16" 90,000 ac-ft 10,000 ac-ft
Kalispell Valley (perched aquifers). Geology and groundwater resources of the Kalispell Valley, Montana: MBMG Bull. 68, 1968.	67,000 acres 40' 27' .10	15" 180,000 ac-ft 21,000 ac-ft

UNCONSOLIDATED AQUIFERS

No. of wells Depths Yields	Quality Temperature Water table	Pump test data Geologic source Uses	Remarks Index map number River basin code no.
10+ 10'-60' Small to moderate	D satisfactory ——— 6'-12'	——— Alluvium S, D	35 43QJ
30+ 21'-299' 30-75 gpm Potential 250-1000 gpm	D 1, Irr. 1 47°F 2'-133'	Sp. Cap. 30-75 gpm/ft. Trans. (1 well only) 2000 gpd/ft. Alluvium S, D, Mun.	58 76D
——— 12'-119' Average 80 gpm (Some small flows)	D 1-5, Irr. 1 ——— 2'-88'	Specific Capacities 5 gpm/ft. Alluvium S, D, Irr.	2 76G
225+ 3'-250' 10-1200 gpm	D 1, Irr. 1 ——— Above surface (In flowing wells) to –150'	Specific Capacities* 1-50 gpm/ft. (in alluvium) Trans.* 20,000-175,000 gpd/ft. (in alluvium) Alluvium and Tertiary S, D Irr., Ind., Mun.	*See Deer Lodge Valley area summary page for more pump test data. 7000 ac-ft/yr. pumped from wells. 34, 37, 56 76G
85+ 5'-47' (flood plain) 11'-365' (high terraces) 250-1000 gpm	D 1, Irr. 1 ——— 2'-22'	Specific capacities in alluvium 8-230 gpm/ft. In Tertiary deposits 3-9 gpm/ft. Alluvium S, D, Irr.	25, 30 76H
40+ 52'-303' 14-385 gpm	D 2-3, Irr. 2-5 53°-120° +55' to –100'	——— Alluvial artesian S, D, Irr.	3 76L
——— 10'-75' 200-500 gpm	D 1, Irr. 1 ——— 5'-25'	——— Alluvium (Valley fill)	About 300 acres waterlogged 12 76L
109+ 6'-94' Up to 10 gpm 70-200 gpm potential	D 1-5, Irr. 1 47°-52° F 3'-52'	Trans. 570,000 gpd/ft. (in outwash, sand, and gravel) Alluvium S, D, Irr.	49, 53, 20 76LJ

TABLE 1—(Continued)

GROUNDWATER DATA FOR TH

Area summarized Publication or other sources	Area of aquifer Permeable thickness Saturated thickness Specific yield	Precipitation Available storage Perennial recharge
Kalispell Valley (shallow artesian aquifer). Geology and groundwater resources of the Kalispell Valley, Montana: MBMG Bull. 68, 1968.	3,800 acres? 60'± ——— ———	15" ——— ———
Kalispell Valley (deep artesian aquifer). Geology and groundwater resources of the Kalispell Valley, Montana: MBMG Bull. 68, 1968.	146,000 acres 364' (Known from only 1 well) ——— ———	15" ——— 30,000 ac-ft
Kalispell Valley (alluvial gravel aquifer). Geology and groundwater resources of the Kalispell Valley, Montana: MBMG Bull. 68, 1968.	34,800 acres 28' 25' .20	15" 170,000 ac-ft 21,000 ac-ft
Kalispell Valley (alluvial sand aquifer). Geology and groundwater resources of the Kalispell Valley, Montana: MBMG Bull. 68, 1968.	18,000 acres 35' 28' .1	15" 50,000 ac-ft 4,000 ac-ft
Missoula Basin. Geology and groundwater resources of the Missoula Basin, Montana: MBMG Bull. 47, 1965.	77,000 acres 300' 200' .1	12" 1,750,000 ac-ft 50,000 ac-ft

Abbreviations in this table pertaining to use of groundwater are:

D—Domestic
Ind—Industrial
Irr.—Irrigation
Mun—Municipal
S—Stock

UNCONSOLIDATED AQUIFERS

No. of wells Depths Yields	Quality Temperature Water table	Pump test data Geologic source Uses	Remarks Index map number River basin code no.
21+ 103'-126' 3-10 gpm flows	D 1, Irr. 1 50° +19' to -21'	Sp. Cap. .3 to .5 gpm/ft. Valley artesian system—alluvial S, D, Irr.	49, 53, 20 76LJ
213+ 109'-480' Flows 1-225 gpm Potential 1500 gpm	D 1-5, Irr. 1 48°-66° F +36' to -174'	Sp. Cap. .3 to 1.9 gpm/ft. Trans. 360-3800 gpd/ft. Valley artesian system—alluvial S, D, Irr., Ind., Mun.	Estimated coefficient of storage, $S = 8.7 \times 10^4$ 49, 53, 20 76LJ
82+ 18'± 250-480 gpm Potential 1500 gpm +	D 1, Irr. 1 ——— 12'±	Sp. Cap. 260-370 gpm/ft. Trans. (average) 1,100,000 gpd/ft. Alluvium S, D, Irr., Ind., Mun.	This aquifer has the best potential for further development in this area. 49, 53, 20 76LJ
46+ 9'-35' Low	D 3-5, Irr. 1 48° (1 only) 7'-22'	Trans. 7500 gpd/ft. Alluvium S, D	49, 53, 20 76LJ
276+ From less than 175' to 550' Up to 5000 gpm	D1, Irr. 1, Ind. 1 (with few exceptions) ——— Less than 50' to 290'	Specific Capacities 150-266 gpm/ft. Trans. 85,000-1,800,000 gpd/ft. Alluvium S, D, Irr., Ind.	40, 42, 12 76M

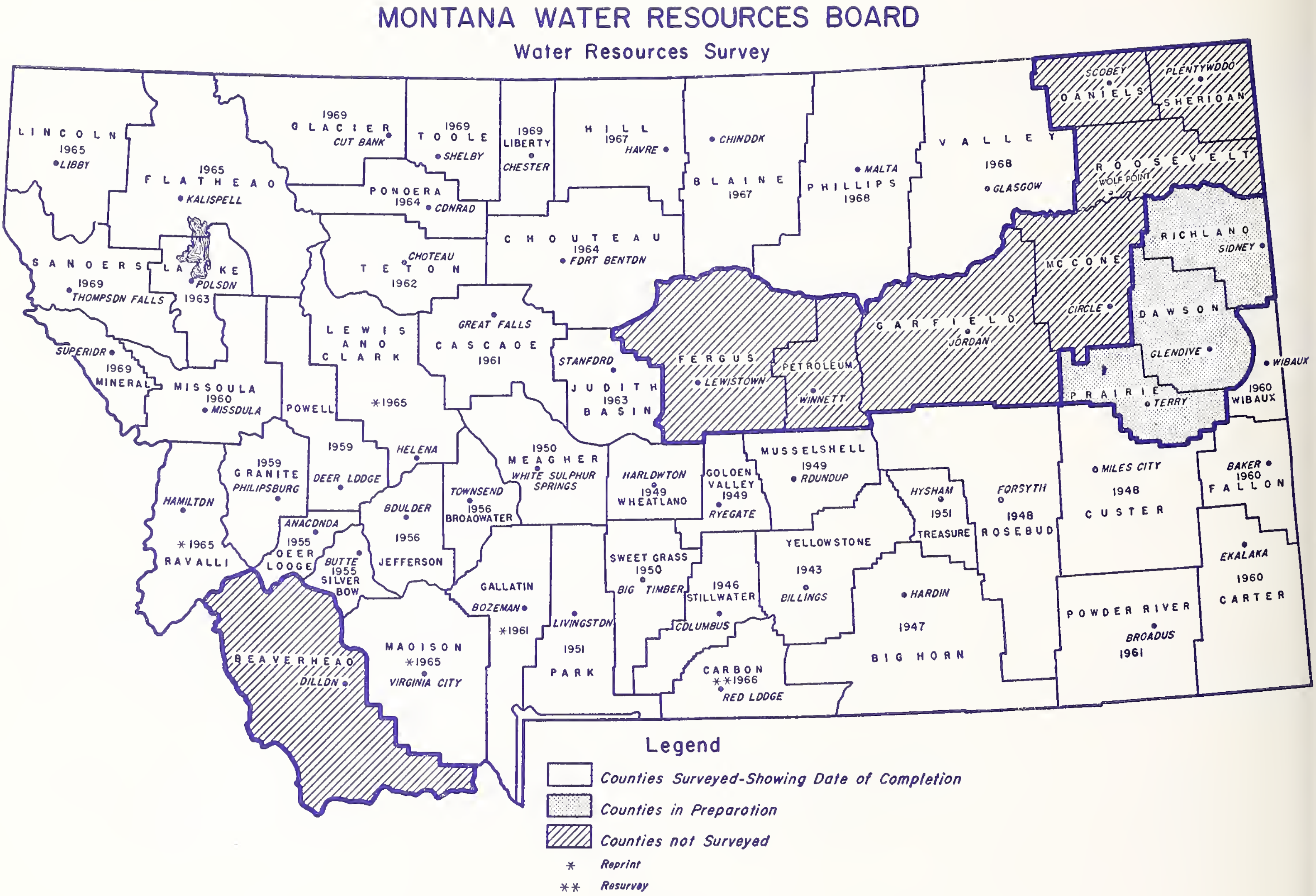


FIGURE 53

UNCONSOLIDATED AQUIFER DATA FROM WATER RESOURCES SURVEYS

Water Resource Surveys of the Montana Water Resources Board provide a good deal of groundwater information in areas not covered or only partially covered by the groundwater investigations listed on the charts and in area summaries for this compilation. The material below has been summarized from the Water Resources Surveys of the six county surveys that provide a comprehensive groundwater section.

Figure 53 shows the counties for which Water Resource Surveys have been published, and those that are now in preparation.

Blaine County

In Blaine County water from the Milk River alluvium is highly mineralized with from 2,400 to 4,400 ppm of total dissolved solids. Wells commonly yield 7 to 15 gpm from depths of 10 to 140 feet. The alluvium of the Missouri River also yields highly mineralized water and is considered bad even for stock water at depths shallower than 50 feet.

Outwash gravels and ice margin deposits in northeastern Blaine County yield as much as 30 gpm of good water to wells from depths of 10 to 150 feet.

Hill County

Terrace gravels in the Bearpaw Mountains in Hill County yield water to wells from depths of 35 to 45 feet at the rate of about 10 gpm.

Shallow gravels in the valleys of Box Elder, Spring, Beaver, and Bullhook Creeks produce 4 to 20 gpm from depths of 25 to 70 feet.

Aquifers in sand and gravel at depths of 30 to 200 feet producing 5 to 40 gpm are reported in Sage Creek valley, one well reporting a flow of 100 gpm from the interval between depths of 169 and 175 feet.

Liberty County

In Liberty County, few wells produce from the Marias River floodplain aquifers. Yields are variable, wells 12 to 150 feet deep producing 3 to 80 gpm. Total dissolved solids in water from the shallow unconsolidated aquifers are reported as frequently less than 1,000 ppm, a good to fair quality of water. Water-bearing sands and gravels, locally more than 50 feet thick in glacial deposits, produce water from depths of 125 to 400 feet. Valley-fill sands and gravels are reported to supply water from depths of 10 to 150 feet in Cottonwood Creek valley.

Phillips County

Irrigated acreages are scattered in Phillips County except for extensively irrigated strips along the Milk River from west of Dodson to the Malta area, and the Beaver Creek drainage from south of Lake Bowdoin to east of Saco. Areas subject to appreciable recharge from irrigation are in the Milk River and Beaver Creek drainages. The Milk River alluvium is not a good aquifer and very few wells have been drilled. For these reasons determinations of aquifer thickness, groundwater in storage, and perennial recharge would be difficult to compute.

Malta's municipal well pump test showed a specific capacity of more than 300 gpm/ft.

Alluvial materials along tributaries north of the Milk River contain water at depths of 15 to 60 feet, but well yields are less than in the Milk River valley.

The Beaver Creek drainage, mentioned above, contains numerous wells 30 to 140 feet deep from which yields of 5 to 25 gpm are reported. This area contains about 24,000 acres subject to considerable recharge from irrigation. If greater well yields can be obtained in this area, the use of groundwater might be increased substantially.

Water quality is variable, ranging from about 500 ppm to 4,000 ppm total dissolved solids.

Analyses of water from wells in the Malta area list dissolved solid contents of 700 ppm to about 1,800 ppm.

In the Saco vicinity total dissolved solids content is reported as 400 to 3,400 ppm, and in the Dodson area the range is from 850 to 3,250 ppm. Between Dodson and Malta the analyses of water from the shallow wells are reported as 2,100 to 2,500 ppm.

Toole County

Glacial deposits in Toole County are reported as about 100 feet thick in most areas; thicknesses approach 200 feet in the buried Marias River valley. Relatively few wells have been drilled into the valley-fill aquifers, those south of Shelby reporting valley fill at least 90 feet thick and containing 20 to 45 feet of sand and gravel. Six municipal wells near Shelby yield 30 to 300 gpm from an aquifer 10 to 15 feet thick. Other wells, which may be producing from valley-fill aquifers or outwash sands and gravels, report yields of 4 to 40 gpm from depths of 20 to 50 feet. Reported quality of water from glacial aquifers is good, about 600 ppm total dissolved solids.

Valley County

Buried valley fill under the Milk River flood plain is an important source of potable water in Valley County. Depths to water vary from 45 feet to nearly 200 feet, and sand and gravel thicknesses range from 5 to 20 feet. Most wells yield 10 to 20 gpm, but Glasgow has three municipal wells each yielding 1,000 gpm.

A few wells along the Missouri River pump water from sands and gravels in wells 10 to 110 feet deep that yield 10 to 25 gpm at drawdowns of about 10 feet. These figures indicate relatively low specific capacities of 1 to 2.5 gpm per foot.

Quality is reported as variable, total dissolved solids ranging from about 1,000 to 3,500 ppm. Only a few wells yield water that might be classified as good to fair, but almost all wells provide satisfactory stock water.

The Flaxville Formation gravels, 10 to 30 feet thick, provide good water from wells 20 to 100 feet deep at rates of 10 to 100 gpm.

UNCONSOLIDATED AQUIFER DATA FROM WATER RESOURCE SURVEYS AND MONTANA HIGHWAY DEPARTMENT TEST HOLE LOGS

Some estimates of aquifer areas have been made by the compiler on the basis of figures for irrigated acreages provided in the county Water Resources Surveys. Some of these areas have been estimated as different from the irrigated areas by determining the extent of alluvial areas shown on U. S. Geological Survey geologic and topographic maps. Estimates of depth of permeable materials in the unconsolidated aquifers have been made from Montana Highway Department test hole logs.

Granite County

In Granite County on the basis of figures from the sources mentioned above, estimates of groundwater data were developed for the unconsolidated aquifers along the Clark Fork River, Flint Creek, and Lower Willow Creek. The estimates were not considered to be accurate enough to include with the summaries of the regular groundwater reports, but are believed to be conservative estimates useful for planning. Along the Clark Fork River in Granite County, the alluvial aquifer is estimated to have an area of about 9,000 acres containing permeable sands and gravels averaging 40 feet in depth. The saturated thickness averages 20 feet and the specific yield is estimated at .15, therefore the Clark Fork alluvial aquifer contains about 27,000 acre-feet of water in storage and available to wells. Recharge is estimated at 4,500 acre-feet annually, which is far in excess of the amount used in this well-watered area. If the time comes when the water can be put to use, wells having a potential yield of 250 to 1,000 gpm can be developed along the Clark Fork River in the vicinity of Drummond and for a considerable distance up Flint Creek to the area around Philipsburg.

For Flint Creek and Lower Willow Creek together, the estimate for area of the aquifer is 8,000 acres and the specific yield remains at .15. Average thickness of permeable materials is 30 feet and the average saturated thickness is 15 feet. Available storage is estimated at 18,000 acre-feet and perennial recharge at 3,000 acre-feet.

Stillwater County

In Stillwater County along the Yellowstone River, alluvium covers about 25,000 acres. From Montana Highway Department test hole logs it was determined that the average permeable thickness is 40 feet containing 15 feet of saturation. On the basis of .15 for specific yield, water in available storage amounts to about 56,000 acre-feet, and perennial recharge, most of which is provided by the river and applied irrigation water, is estimated to be about 9,000 acre-feet.

Similar estimates were attempted in a few other areas along major streams, but were not completed due to limited numbers of logs and small alluvial areas.

UNCONSOLIDATED AQUIFER DATA FROM UNPUBLISHED REPORTS

The files of the U. S. Geological Survey were the source of information for the Medicine Lake area of Roosevelt and Sheridan Counties, where water is obtained from three zones in the glacial drift. The water is generally hard but low in total dissolved solids, except in the shallow zone, where sulfate content may exceed 4,000 ppm. Of the other two aquifers in the drift, one is near the middle, and one is at the base.

Glacial outwash channels are the largest ground-water reservoirs in this area, but the quality of the water is not reported.

Alluvium in the Big Muddy valley contains large quantities of groundwater, but fine sand makes development of wells difficult. The quality is comparable to that in the two lower zones in the glacial drift. Kames, eskers, and the lower terraces are sources of good water, generally suitable for domestic use. The community of Plentywood is located on terrace deposits that provide water to many wells.

Wells in the unconsolidated aquifers range from 20 to 233 feet deep and the water table is at 10 to 188 feet. Water-table fluctuation is from 0 to 13 feet in Roosevelt County and 0 to 2 feet in Sheridan County. Some of the deeper wells may be producing from the preglacial Missouri River drainage course, which trends northeast from Medicine Lake to the State line.

AQUIFERS IN PREGLACIAL AND TEMPORARY GLACIAL CHANNELS

The channels of the Milk River, Missouri River, and their tributary rivers in Montana were changed as a result of glaciation. The advancing continental ice sheet blocked the preglacial channels, ponded the rivers, and forced them to seek new channels. The sands and gravels in the preglacial channels were covered with glacial till, a mixture of clay, sand, gravel, and boulders, which is generally almost impermeable. In some areas these channel remnants are still discernible, but in others they have been filled so that little or no surface expression of the former channel remains. Figure 54 shows major segments of preglacial drainage courses.

Good aquifers are known to exist in several areas of these preglacial channels, especially near Big Sandy, Havre, Glasgow, Malta, Poplar, and Shelby. Details of the preglacial channel aquifer in the Big Sandy vicinity are given in the individual area summary for the Lower Marias irrigation project, item 28 on the index map, Figure 1.

With the evidence at hand of good aquifers in these preglacial channels, it seemed probable that similar aquifers might exist in preglacial channels in other areas that had not been included in previous groundwater investigations.

Professional Paper 174 of the United States Geological Survey, entitled "Physiography and Glacial Geology of Eastern Montana and Adjacent Areas," contains maps showing these preglacial channels and also channels that were used temporarily during glacial advances.

The groundwater appropriation files of the Montana Water Resources Board were searched for wells in the area of the abandoned channels, but in general few wells were found other than in areas already mentioned.

In Garfield County, records of seven wells were found, so located that they might have been producing from an abandoned temporary glacial channel. Indicated well yields are 2 to 15 gpm.

In McCone County, the few logs available indicate that even in areas mapped as abandoned temporary glacial channels, where water-bearing sands and gravels are encountered at depths of less than 100 feet, the water is being produced from the Fort Union Formation at depths of 150 to 200 feet. This might be an indication that the water in the alluvium is of poorer quality than that from the bedrock source in the Fort Union.

In Richland and Dawson Counties, few wells were found that seemed to be producing from unconsolidated aquifers.

In Roosevelt County near Poplar, two wells within the limits of a mapped preglacial channel produce 250 and 400 gpm, respectively; each has a specific capacity of 10 gpm/ft. Other than these two, only a few logs were found for wells producing from aquifers in the preglacial channels, and these showed indicated yields of 4 to 25 gpm.

In the Medicine Lake area of Sheridan County, many of the deeper wells are probably producing from the abandoned preglacial Missouri River channel.

In southern Chouteau County, a few wells near Norbert and Highwood produce 100 to 300 gpm seemingly from aquifers in abandoned channels.

In Blaine County, the Milk River flows in the abandoned preglacial channel of the Missouri River, and the groundwater from the alluvium is strongly mineralized, containing 2,400 to 4,400 ppm total dissolved solids. Wells commonly yield 7 to 15 gpm.

In Hill County, the preglacial channel aquifers near Havre produce 125 to 300 gpm of excellent to good water for municipal use. Near Big Sandy, yields are lower, ranging from 15 to 50 gpm, but a potential exists for yields of 250 gpm.

In Phillips County, aquifers in the buried preglacial Missouri channel under the Milk River alluvium are at depths of about 50 to 200 feet and range from 1 foot to 10 feet thick, although records list thicknesses of 40 to 60 feet. Yields are commonly 5 to 25 gpm, but some wells produce 50 gpm and the best wells produce 1,000 gpm. Some wells pumping at about 750 gpm have rated specific capacities of about 30 gpm/ft. A municipal well at Malta has a specific capacity of more than 300 gpm/ft. Analyses by the Montana State Board of Health show the quality of water from the Malta wells to be good, less than 1,000 ppm total dissolved solids.

In Valley County, the Milk River follows the abandoned preglacial Missouri channel downstream to the vicinity of Nashua. Here the aquifer in the buried valley ranges from 5 feet to about 200 feet in thickness and lies at depths of 45 to 200 feet. Well yields are reported as 10 to 20 gpm. Municipal wells at Glasgow produce 100 gpm from depths of 108 to 121 feet.

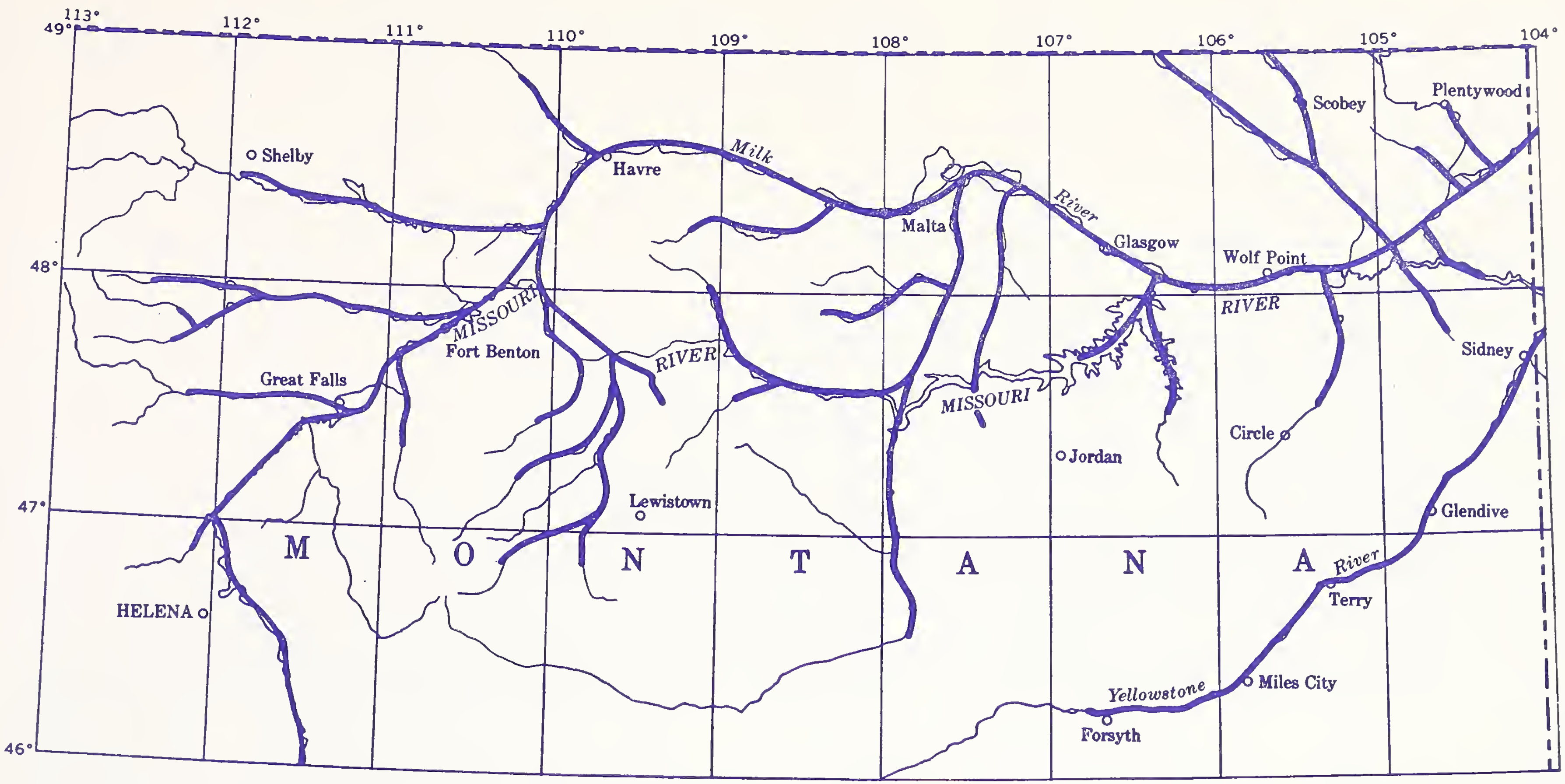
In Toole County, a few wells draw water from the buried valley-fill aquifers south of Shelby. Here the valley-fill is about 90 feet thick and includes 20 to 45 feet of sands and gravels. Municipal wells in Shelby reportedly pump 30 to 300 gpm. Two wells south of Sweetgrass flow 40 gpm of good water from gravels at a depth of about 140 feet.

Abandoned temporary glacial or preglacial channels are known in several other areas in Montana, but not enough well records were found for these areas to permit even an approximate evaluation.

As mentioned earlier, abandoned channels may show no surface evidence of their location. In areas where water is hard to find, prospecting for buried-channel aquifers may provide hitherto untapped sources of groundwater. The quality of the water will vary, as shown by examples from known sources, and quantities available for appropriation will be small in comparison to areas where recharge is greater.

References:

Glacial Map of Montana East of the Rocky Mountains, U. S. Geological Survey Map I-327, 1961.



Compiled from Calhoun (1906), Alden (1932), and others

SKETCH MAP SHOWING MAJOR SEGMENTS OF PREGLACIAL DRAINAGE COURSES

FIGURE 55

GENERALIZED LIST OF STRATIGRAPHIC UNITS AND THEIR HYDROLOGIC CHARACTERISTICS

Period		Stratigraphic Units	Hydrologic Characteristics
Quaternary		Alluvium Terrace deposits	Excellent aquifers, high storage and recharge capacities, high yields locally, water quality generally excellent.
		Glacial deposits	Locally good aquifers, fair to good storage and recharge capacities, variable yields, water quality excellent to poor.
		Alluvium Terrace deposits	Locally excellent aquifers, medium to high storage and recharge capacities, variable yields, water quality excellent to poor.
Tertiary		Valley-fill deposits	Good aquifers in semi-consolidated to consolidated thin sandstone and conglomerates interbedded with volcanic ash and clays, some valley type artesian systems, high storage but generally low recharge capacity. Wells flow as much as 125 gpm in the Helena Valley, and can be pumped at about 1,000 gpm in the Deer Lodge Valley and up to 1,500 gpm in the Kalispell Valley. Water quality is excellent to fair. Many wells produce water from a common aquifer in both Tertiary and Quaternary Sediments.
		Flaxville Formation	Locally good aquifers, medium storage—low recharge capacities, water quality excellent to fair.
	**LIVINGSTON FORMATION	Fort Union Formation	Good aquifers in sandstones and coal beds, fair storage and recharge capacities, small to moderate yields. Water quality good to poor. Flowing wells in many areas with small yields.
		Hell Creek Formation	Good aquifers in sandstones, good storage and recharge capacities, water quality excellent to poor. Flowing wells with small yields in many areas. Shares a common aquifer with Fox Hills Fm. (below) on Cedar Creek Anticline with flows up to 65 gpm.
		Fox Hills Formation	Similar to sandstones of Hell Creek Formation.
		Bearpaw Formation	Poor aquifer, low yields, water quality generally poor.
		Judith River Formation	Good aquifers in sandstones, good storage and recharge capacities, yields small to moderate, flowing wells in many areas with small to moderate yields, water quality excellent to poor, (Parkman Fm.) in Big Horn County, Two Medicine Fm. in Glacier County and Toole County are similar.
Cretaceous		Claggett Formation	Important aquifer only in Wheatland County near Harlowton, yields generally low —a few small flows.
		Eagle Formation	Excellent aquifers in sandstones, particularly the lower member, (Virgelle ss.) medium to high storage and recharge capacities yields small to as much as 250 gpm, quality excellent to fair. A few wells flow at rates up to 75 gpm.
		Colorado Shale	Generally a poor aquifer—a few flowing wells in Wheatland County supply good quality water from a ss. near the middle. Basal ss. supplies a few wells, and has a good potential, water quality in Judith Basin good to permissible. Basal ss. furnishes good water to flowing wells in Cascade County.
		Kootenai Formation	Basal ss. is an excellent aquifer, other ss. members good aquifers, medium to high storage and recharge capacities, small to moderate yields, flows in Judith Basin up to 250 gpm, water quality excellent to fair, (in Big Horn County Cloverly Fm. is similar). A flow in excess of 1,000 gpm is reported in Wheatland County.
Jurassic		Morrison Formation	Not an important aquifer—some potential in ss. members.
		Ellis Group	Not an important aquifer—capable of moderate yields and flows from the Swift Fm.* in Judith Basin and small yields in Cascade County.
Triassic		Chugwater Formation	An excellent aquifer near Big Horn Mtns. Potential flowing yield of 1,500 gpm in Carbon County, high storage and recharge capacities, high yields, water quality good.
		Tensleep Sandstone	An excellent aquifer on the flanks of the Big Snowy and Big Horn Mtns., high storage and recharge capacities, initial flows 2,000 gpm in Big Horn County with sustained flows 200 gpm, of slightly mineralized water.
Pennsylvanian		Amsden Formation	Excellent aquifer in Big Horn and Carbon Counties, high storage and recharge capacities, 3,700 gpm flow from combined Amsden-Tensleep aquifer in Carbon County, water quality good.
Mississippian		Madison Limestone	An excellent aquifer in Carbon County, a good aquifer in Cascade County, high yields of unpotable water in Big Horn County, cavernous porosity in some areas. Potential flows of 3,000 gpm in Carbon County. Water quality good to poor.

Pre-Mississippian rocks are presently of little importance as aquifers. Wells developed in them will most likely result from oil tests being converted to water wells if large quantities of fresh water are encountered. A few wells draw water from the Precambrian Belt Series rocks in the Kalispell area.

**Permeable zones in the Livingston Formation provide small yields of excellent quality water in Park County and Sweet Grass County. Small yields in Meagher County are pumped from Livingston Formation.
The Livingston Formation is equivalent in age to formations from the lower part of the Fort Union down to the Eagle sandstone.

*Member of Ellis Group.

Bedrock Aquifers

Areas in which bedrock wells are referred to in published reports are shown on maps prepared for the Fort Union, Hell Creek and Hell Creek-Fox Hills, Judith River, and Kootenai Formations. The Hell Creek and Fox Hills Formations are shown on the same map because the artesian aquifer on the Cedar Creek Anticline occurs in both the basal Hell Creek and in the Fox Hills sandstones. Wells referred to the Lance Formation in the older reports are also shown on the Hell Creek-Fox Hills map.

Wells referred to the Parkman Formation in Big Horn County and to the Two Medicine Formation in the Cut Bank area of Glacier and Toole Counties are shown on the same map as the Judith River Formation wells.

The maps show the generalized outcrop area of the formation, and an outline of the areas in which the wells are located. These areas have been delineated because the actual locations of the wells are known from published records, while in other areas only general information is available concerning well locations, depths, water table, water quality and the yield of the wells. Each of the areas is numbered, and a brief listing of well data is provided for each area, either on the same page with the map or on the page facing the map. The original sources of the information for each area can be found by referring to the corresponding area on the index map, Figure 1.

MAJOR BEDROCK AQUIFERS

Fort Union Formation

The Fort Union Formation consists of beds of sandstone, shale, and coal, having a known thickness of as much as 2,200 feet. The Fort Union Formation is at the surface over vast areas of eastern Montana and in several areas of south-central Montana.

A water-bearing sandstone is penetrated by most wells at depths of 100 to 300 feet in the Fort Union Formation. Coal beds provide potable water in some areas, but the water may have a brownish tinge. The shale beds are relatively impervious and yield little if any water to wells. However, the shale beds tend to confine water in underlying porous sandstones, giving rise to flowing wells in structurally favorable areas.

The map, Figure 56, shows six areas in which wells producing from the Fort Union Formation are referred to in published reports.

In addition to the specific areas shown on the map, it is known from general ground-water studies that most wells 100 to 300 feet deep in the Fort Union Formation will find adequate supplies of potable water in northern Carter County and Fallon County.

Sandstone and coal beds of the Fort Union Formation are capable of yielding small supplies of ground water for domestic and stock use in Carbon County.

In Daniels County water quality ranges widely in wells in the Fort Union Formation and yields are generally small.

In the Buffalo Grazing District in northeastern Yellowstone County, Fort Union wells produce from depths ranging from 10 to 400 feet. In this area the Fort Union Formation is about 2,000 feet thick. Domestic and stock wells commonly produce from 5 to 20 gpm, and total dissolved solids range from about 300 to 1,500 ppm.

In Powder River County, groundwater is plentiful in the Fort Union Formation at depths of 100 to 300 feet in areas 2 to 5 miles west of the Powder and Little Powder Rivers.

In Prairie County, groundwater is plentiful in Fort Union sandstone beds at depths of less than 300 feet.

In Garfield County, groundwater in the Fort Union Formation is limited to the upper (Tongue River) member in the eastern part of the county.

Unpublished information in the files of the U. S. Geological Survey has been drawn upon for information on Roosevelt and Sheridan Counties, where wells in the Fort Union Formation are 24 to 370 feet deep. The water table ranges from 12 to 250 feet deep and shows only a small range of seasonal fluctuation. Several aquifers have artesian pressures, but yields are generally small. The water from depths greater than 100 feet is soft, but moderately to strongly mineralized, and water from lignite beds in the Fort Union at many locations is unfit for domestic use.

In Valley County, wells in the Fort Union Formation are 70 to 100 feet deep or more and yield 5 to 30 gpm; flowing wells are completed in topographically low areas. The water is relatively low in total dissolved solids, but sodium content may be high.

In almost the entire outcrop area of the Fort Union Formation, wells 30 to 300 feet deep will

MAP SHOWING GENERALIZED OUTCROP AREA OF THE FORT UNION FORMATION, WITH WELL AREAS OUTLINED.

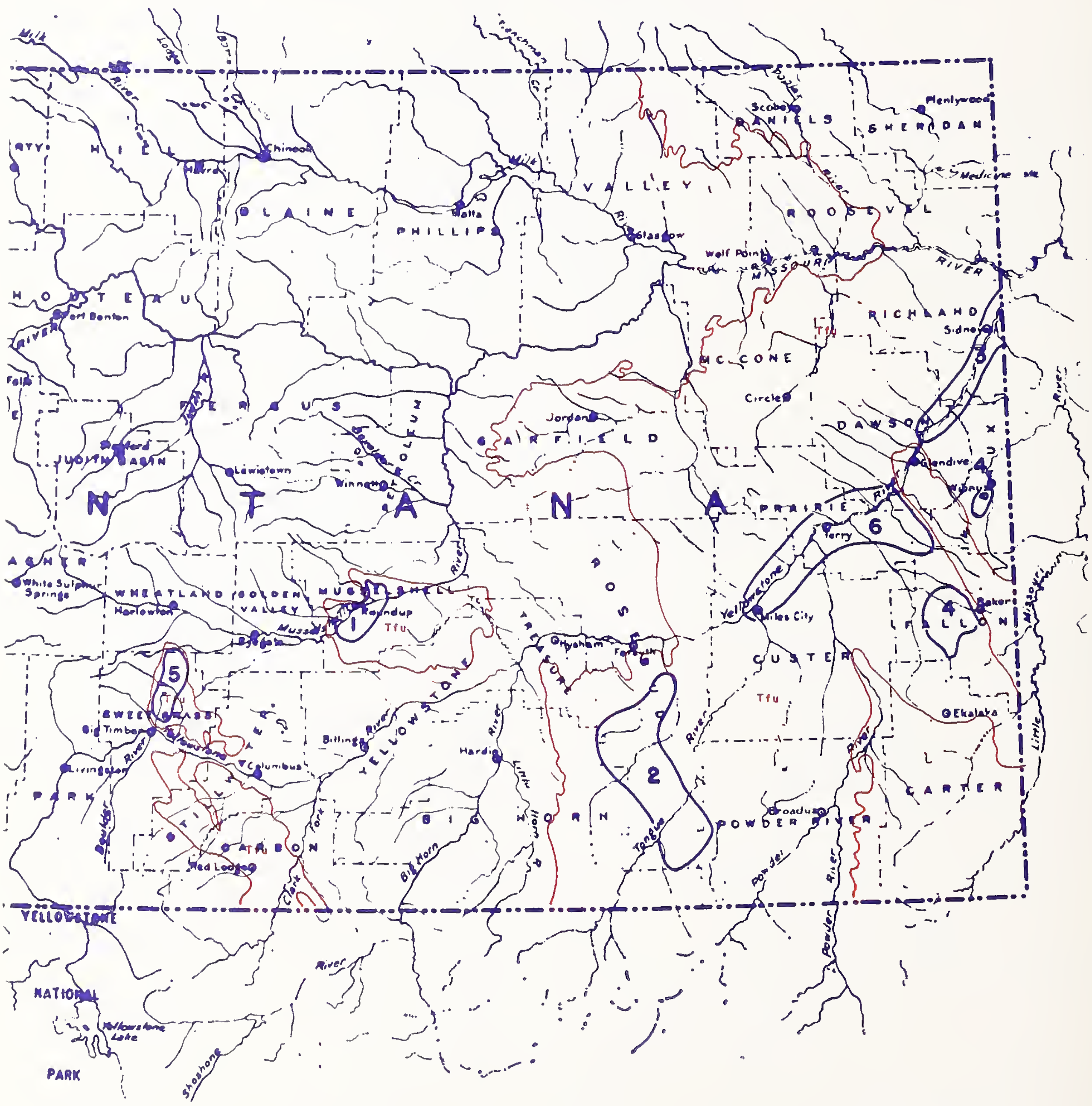


FIGURE 56.—FORT UNION WELL DATA SUMMARIES.

1. Wells 17'-1,000' deep
   Water table at 5'-161'
   Specific capacity
   1 well, 10 gpm/ft.
   Yields 5-200 gpm
   Some flows
   Quality, domestic 2-5

2. Wells 26'-340' deep
   Water table 11'-105'
   Yields 3-10 gpm
   Some flows 1-15 gpm
   Quality, domestic 1-5

3. Wells 25'-500' deep
   Water table at 11'-126'
   Some flows .5 to 25 gpm
   Quality, domestic 2-5

4. Wells 30'-350' deep
   Water table at 21'-176'
   Some flows 1-69 gpm
   Quality, domestic 2-5

5. Wells 50'-300' deep
   Yields to 50 gpm
   Some small flows
   Quality, domestic—potable

6. Wells 18'-312' deep
   Water table at 8'-35'
   Small yields
   Some small flows
   Quality, domestic 2-3

penetrate one to several sandstone beds and will yield adequate supplies of water for stock and domestic use. In most wells the water will be of good to fair quality. Well schedules in the files of the U. S. Geological Survey from Fallon, McCone, Richland, Rosebud, and Prairie Counties list yields ranging from 1 to 60 gpm; most wells yield in the range of 6 to 10 gpm. Specific capacities are generally low, ranging from .01 to .6 gpm/ft.

Hell Creek and Fox Hills Formations

The map, Figure 57, shows eight areas in which wells produce from the Hell Creek, the Fox Hills, or as on the Cedar Creek Anticline, from an aquifer in both the basal part of the Hell Creek and the Fox Hills Formations.

General information on other areas includes that in the Buffalo Grazing District in northeastern Yellowstone County, where wells in the Hell Creek Formation are 100 to 400 feet deep. The Hell Creek Formation in this area ranges from 300 to 1,200 feet in thickness. Production rates are in the range of 5 to 20 gpm, and water averages 1,000 ppm total dissolved solids, ranging from about 300 to 1,500 ppm.

Several wells in and near Terry produce soft water from depths ranging from 300 to 700 feet in the Hell Creek-Fox Hills aquifer. Flows of about 35 gpm at a pressure of 25 psi are reported. Production may be increased to 250 gpm by pumping. The water is reported as strong in sodium bicarbonate and not suited for irrigation.

In Carter County, in the area of Hell Creek and Fox Hills outcrops, water is produced from depths of 100 to 300 feet. The combined thickness of the two formations ranges between 500 and 900 feet in this area.

Water is produced from depths of 100 to 800 feet in the Hell Creek-Fox Hills aquifer in Powder River County; the unit is 800 to 1,000 feet in thickness. The general area underlain by the combined formations is east of the Powder and Little Powder Rivers.

The Hell Creek and Fox Hills Formations in Garfield County yield fair to good water from the lower sandstone beds. Flowing wells along Big Dry Creek produce 1 to 20 gpm from a depth of 200 feet at Jordan. Depths to water increase toward the east.

In Valley County, wells 75 to 350 feet deep produce 5 to 30 gpm on pump.

Judith River, Parkman, and Two Medicine Formations

The map, Figure 58, shows nine areas in which wells producing from the Judith River, Parkman, and Two Medicine Formations are referred to in published reports. The Judith River Formation consists of a few feet to about 400 feet of sandstone, siltstone, shale, and lignite. The Parkman Formation, in this report referred to only in Big Horn County, is 250 to 300 feet thick and consists of interbedded sandstone and shale in the upper part and a basal massive sandstone along the lower Little Bighorn River valley.

The Parkman sandstone is shown on the same map with the Judith River Formation because it is mapped with and regarded as a member of the Judith River Formation on the Geologic Map of Montana, 1955, published by the U. S. Geological Survey.

In the Cut Bank area, numerous wells produce from the Two Medicine Formation, which is at least in part a stratigraphic equivalent of the Judith River Formation. Wells range from 42 to 288 feet in depth, and the water table is at depths of 1 to 250 feet. Yields are generally less than 10 gpm and values for specific capacity and transmissibility are low. The quality of the Two Medicine water ranges from good to unusable for domestic purposes. In this area the Two Medicine Formation consists chiefly of mudstone and siltstone interbedded with sandstone and attains a total thickness of about 500 feet. The outcrop area of the Two Medicine Formation is not shown on the map, Figure 58.

In addition to the areas shown on the map, a few wells produce water from the Judith River Formation in Carbon County, Judith Basin County, and in northeastern Yellowstone County.

In northern Hill County, at Havre Air Force Station, water from the Judith River Formation at a depth of about 900 feet is too mineralized to be used without treatment.

In Stillwater County, the Judith River Formation supplies water to a few wells at rates of 2 to 15 gpm. A few wells yield artesian flows.

In Valley County, wells 300 to 700 feet deep produce 5 to 40 gpm. Some wells flow as much as 20 gpm.

FIGURE 57.— HELL CREEK-FOX HILLS WELL DATA SUMMARIES

1. Golden Valley County
   Wells 25'-252' deep
   Water table at 16'-127'
   Quality, domestic 2-5
   Musselshell County
   Water table at 4'-140'
   Few yields, most 2-3 gpm
   (one 70 gpm)
   Few small flows 1-3 gpm
   Quality, domestic 2-5

2. Yellowstone and Treasure Counties
   Wells 43'-220' deep
   Water table at 8'-150'
   Quality, domestic 1-5
   Lower Bighorn River
   Wells 38'-180' deep
   Water table at 3'-39'
   2 small flows
   Quality, domestic 2-3

3. Wells 19'-590' deep
   Water table at 6'-85'
   Some flows—quantity unreported
   Quality, domestic 2-5

4. (3 wells only)
   92'-684' deep
   Water table at 58'-60'
   Quality, domestic 2-3

5. Wells 60'-135' deep
   Water table at 10'±
   Quality, domestic 3-5
   Sufficient for stock and domestic use

6. (1 well only)
   225' deep
   Small to moderate yield
   Quality, domestic 3

7. Wells 50'-290' deep
   Water table at 20' to 80'
   Mostly small yields,
   30 gpm at Reed Point
   Quality, domestic 2-3

8. Northern Powder River
   Wells 40'-1,200' deep
   Water table at 13' to 470'
   $S = 2.6 \times 10^{-4}$
   Aquifer thickness 250'
   T = 230-1,600 gpd/ft.
   Some flows 1-55 gpm
   Quality, domestic 2

9. Cedar Creek Anticline
   Wells 27'-1,480' deep
   Water table at 13'-366'
   Some flows 1-65 gpm
   T = 230-4,800 gpd/ft.
   Quality, domestic 2-5

MAP SHOWING GENERALIZED OUTCROP AREA OF THE HELL CREEK-FOX HILLS FORMATIONS WITH WELL AREAS OUTLINED

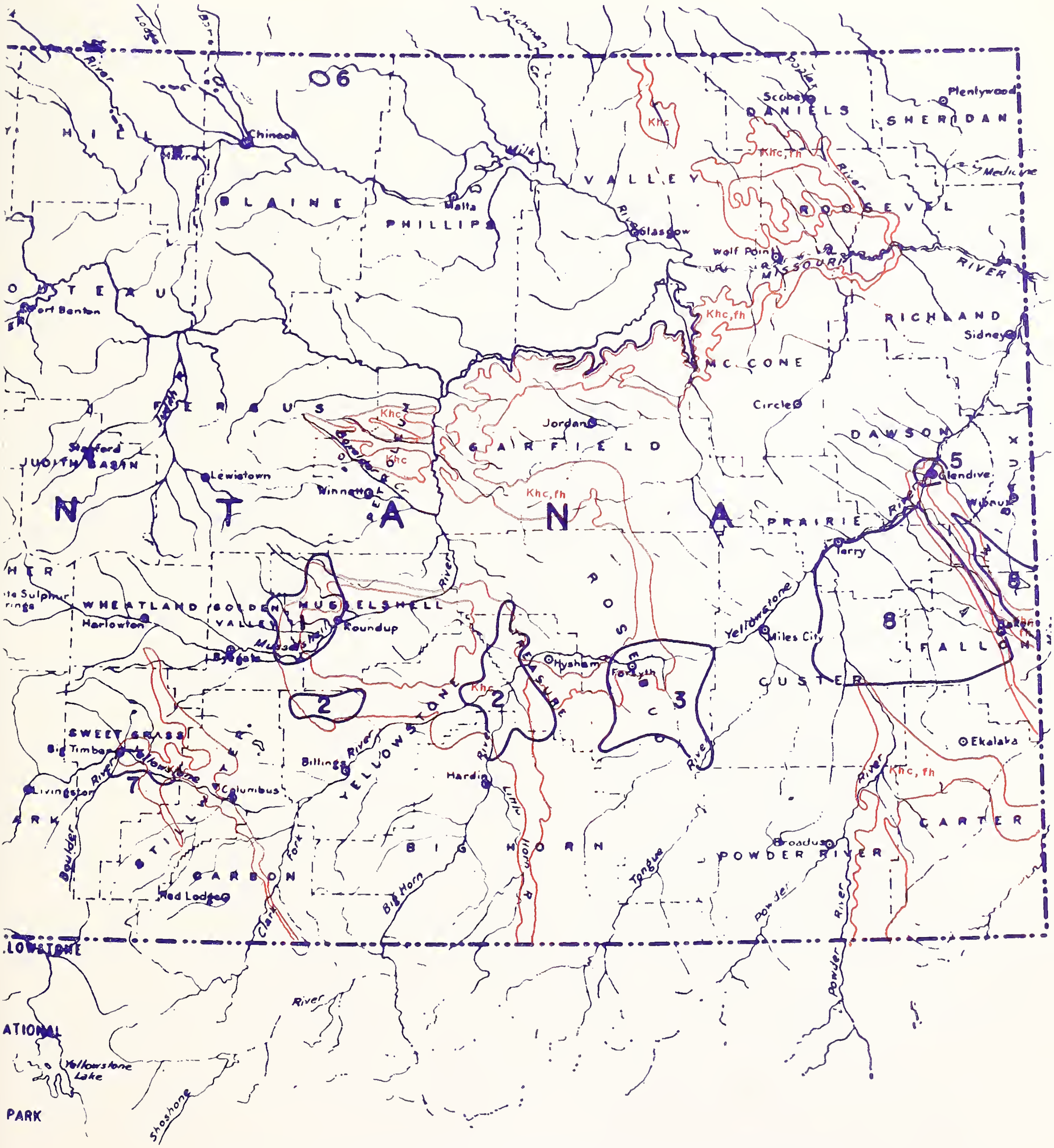


FIGURE 57.— HELL CREEK-FOX HILLS WELL DATA SUMMARIES

FIGURE 58.— JUDITH RIVER, PARKMAN, AND TWO MEDICINE FORMATIONS, WELL DATA SUMMARIES

1. Golden Valley County
   Wells 30'-110' deep
   Water table at 9'-75'
   Quality, domestic 1-5
   Musselshell County
   Wells 36'-535' deep
   Water table at 3'-113'
   Quality, domestic 1-5

2. Wells 10'-317' deep
   Water table at 4'-60'
   Quality, domestic 1-5

3. Wells 700'-1,100' deep
   Flows 1-65 gpm
   Quality, domestic 5

4. Wells 14'-204' deep
   Water table at 11'-80'
   Yields 5-15 gpm
   Quality, domestic 2

5. (Parkman Fm.)
   Wells 100'-210' deep
   Water table at 11'±
   T = 600 to 20,000 gpd/ft.
   Quality, domestic 1-5

6. Blaine County
   Wells 75'-225' deep
   Water table at 2'-15'
   Some flow 1-150 gpm
   Quality, domestic 2-5
   Phillips, Fergus, Petroleum and Garfield Counties
   Wells 155'-2,118' deep
   Flows—few more than 10 gpm
   Water table at 0'-365'
   Sp. cap. (typical) .1 gpm/ft.
   Shut in pressure 1-115 psi
   Highest yield potential 200 gpm
   Quality, domestic 3-5

7. Wells 38'-655' deep
   Small yields
   Quality 2-5

8. (Parkman Fm.)
   Wells 86'-117' deep
   Water table at 50'±
   Quality, domestic 3-5

9. (Two Medicine Fm.)
   Wells 42'-288' deep
   Water table at 1'-250'
   Yields average less than 10 gpm
   Transmissibility as much as 700 gpd/ft.
   Specific capacity (average) .15 gpm/ft.
   Quality, domestic 4-5

MAP SHOWING GENERALIZED OUTCROP AREA OF THE JUDITH RIVER AND PARKMAN FORMATIONS, WITH WELL AREAS OUTLINED

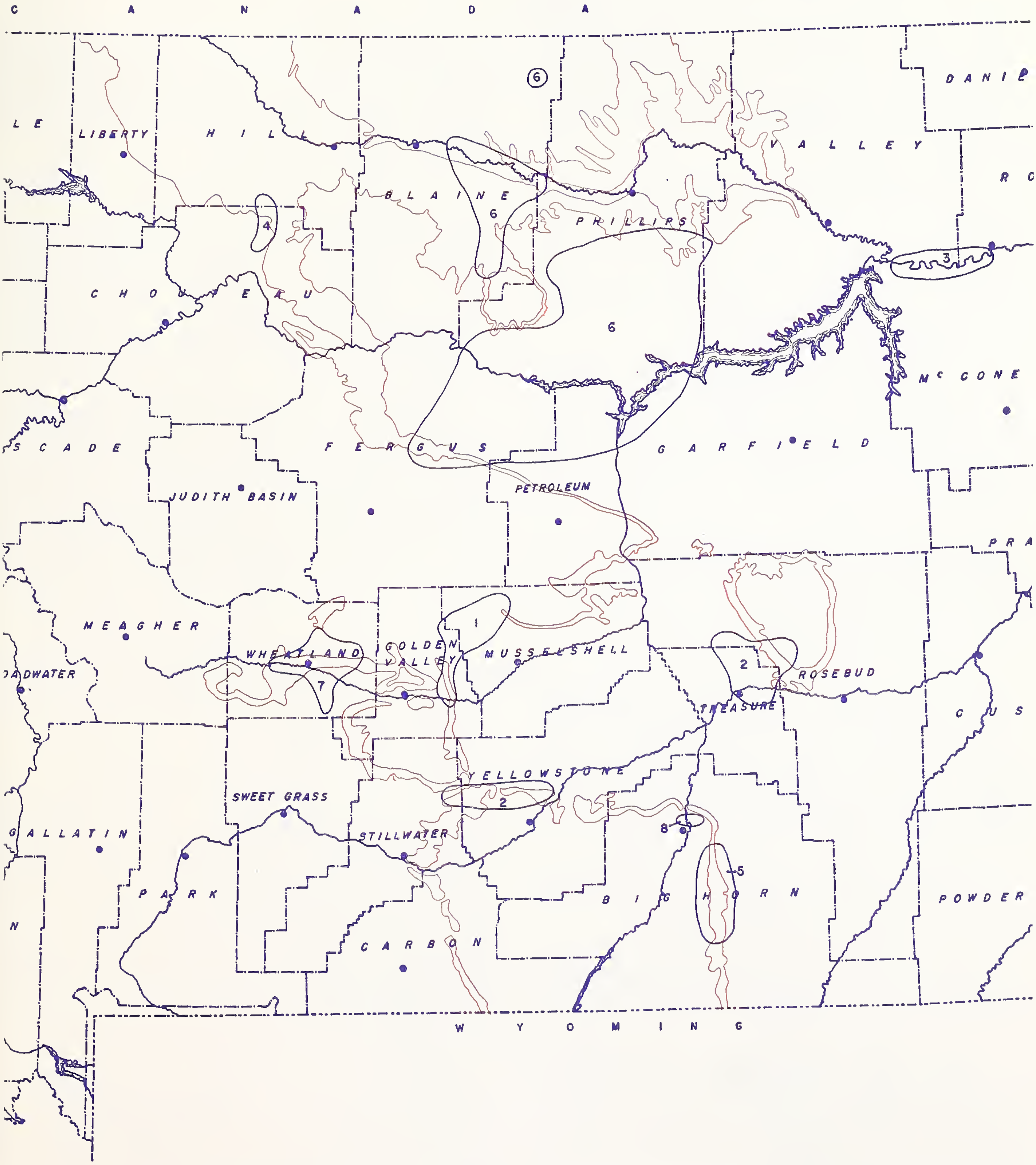


FIGURE 58.—JUDITH RIVER, PARKMAN, AND TWO MEDICINE FORMATIONS, WELL DATA SUMMARIES

Eagle Formation

The Eagle Formation consists of about 250 feet of sandstone, shaly sandstone and a lower massive sandstone member, which is called the Virgelle Sandstone in western Montana. The Eagle is an excellent aquifer, but because it is exposed only in narrow bands around mountain uplifts, the area in which it lies within economic drilling depth is relatively small compared with formations such as the Fort Union or Judith River.

The Virgelle Sandstone — or lower member of the Eagle Formation — supplies many wells in the Cut Bank area. Here the wells range from 21 to 600 feet in depth and the water table is at 19 to 305 feet. Yields are as great as 250 gpm and transmissibilities range from 700 to 50,000 gpd/ft. The quality of the water is good to fair.

In northern Chouteau County, the Virgelle supplies fair to poor water to wells in the area of the Lower Marias Irrigation Project. Here wells range from 393 to 742 feet in depth and the water table is at 12 to 304 feet. Yields are generally small, ranging up to 15 gpm.

In northern Hill County, unpublished records in the files of the U. S. Geological Survey report a well 1,700 feet deep producing strongly mineralized water from the Eagle at a rate of 75 gpm. This water would be unfit for domestic use without treatment.

A few wells on the Fort Belknap Indian Reservation produce small to moderate yields from depths of 83 to 290 feet in the Virgelle Sandstone. Some flows are reported, none exceeding 1 gpm. Water quality in this area ranges from fair to poor, as the water contains moderate to large concentrations of sulfate and iron.

In the Judith Basin, wells 10 to 100 feet deep in the Eagle produce 5 to 50 gpm of fair water, and one well is reported to flow 50 gpm.

Eagle wells produce excellent water at Joliet in Carbon County, but there are few wells of record in this area.

The Eagle Formation supplies a few wells also in Golden Valley, Musselshell, and Yellowstone Counties. In Musselshell County, wells in the Eagle Formation are 43 to 550 feet deep and yield as much as 15 gpm. A few of these wells produce small yields by artesian flow.

In the report area of Hydrologic Atlas 308 (see index map item 57), Eagle wells are stated to flow as much as 75 gpm, although most wells have small yields, owing to reduced permeability in certain localities.

Kootenai Formation

The Kootenai Formation consists of 400 to 500 feet of red shale and brown to gray sandstone. The basal sandstone is about 100 feet thick and is an excellent aquifer. Other sandstone members in the formation are good aquifers.

The map, Figure 59, shows five areas in which wells have been located from published reports. Although some reports use different names for rock units of the Kootenai in various areas, all are referred to the Kootenai Formation on this map. These names include the Cloverly Formation, the Lakota Sandstone, and the driller's terms Second Cat Creek, Third Cat Creek, Sunburst sand, and Cut Bank sand.

In addition to wells in the areas shown on the map, several other wells producing from the Kootenai Formation have been reported. Near Coffee Creek in western Fergus County, a well reportedly flowed 300 gpm. In Lewistown, where the basal Kootenai sand is at a depth of 470 feet, the pressure was reported as 39 psi, sufficient to raise the water about 90 feet above the surface at this locality.

Near Mosby in southwestern Garfield County, a flow of 1,500 gallons per minute of good water was reported. Several other wells in this area, most of which are abandoned oil tests, flowed 50 to 500 gallons per minute.

A few wells in Big Horn County produce water from the Kootenai (Cloverly) Formation. One well flowed 200 gpm, the pressure at the land surface was 80 psi, and the transmissibility was 3,000 gpd/ft. The quality of the water is excellent for domestic use, but unsuitable for irrigation because of excessive sodium content. Other wells in Big Horn County yield 50 to 500 gpm from wells 395 to 3,500 deep. The deeper wells are beyond economic drilling limits for water except where abandoned oil tests can be converted to water wells.

A well near Lodge Grass is used to irrigate hay fields, and although the water is unsuitable for irrigation according to accepted standards, no ill effects had been observed as late as 1954. The well was drilled in 1928, and according to the log, is producing from a 15-foot sand layer at a depth of 3,365 to 3,380 feet.

MAP SHOWING GENERALIZED OUTCROP AREA OF THE KOOTENAI FORMATION, WITH WELL AREAS OUTLINED

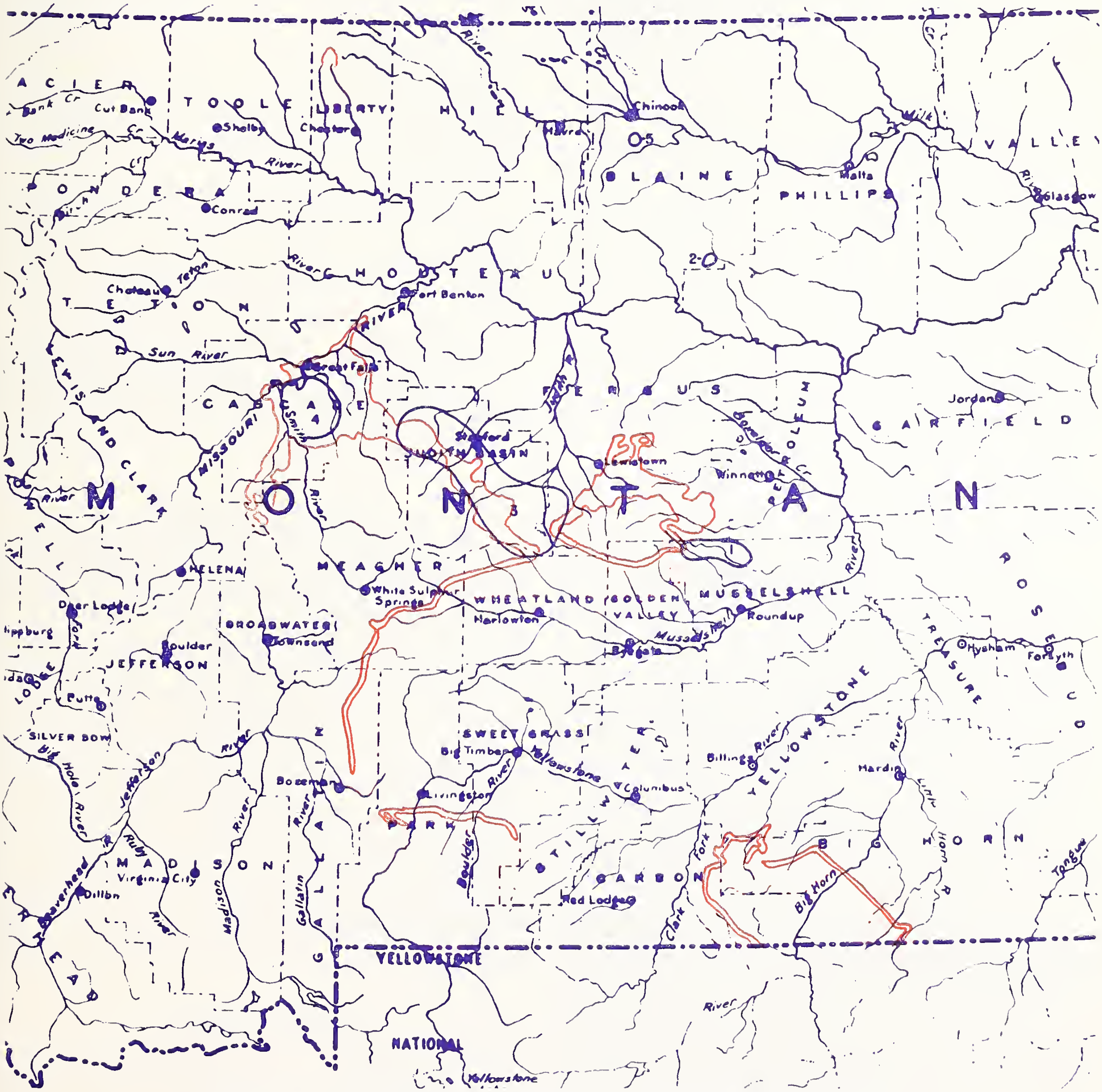


FIGURE 59.— KOOTENAI FORMATION WELL DATA SUMMARIES.

1. Musselshell County
   Wells 13'-250' deep
   Water table at 5'-186'
   Quality, domestic 2
2. Fort Belknap Indian Reservation
   Wells 191'-260'
   Flows up to 4 gpm
   Quality, domestic 2-3
3. Judith Basin
   Wells 50'-1,160' deep
   Flows up to 250 gpm
   Transmissibilities 170-1,860 gpd/ft.
   Quality, domestic 1-2, (mostly 1)
4. Stockett Area
   Wells 7'-265' deep
   Water table at 1'-134'
   Yields 2-150 gpm
   Most common yields 5-20 gpm
   Flows 8-20 gpm
   Quality, domestic 2
5. Bowes Oil Field
   Water for industrial use
   Secondary recovery of petroleum
   50 million gallons in 4½ years

Madison Formation

The Madison Formation consists of 700 to 1,500 feet of gray to white and brown limestone, which is characterized by cavernous zones in the upper part.

Madison rocks yield potable water to wells in Cascade County south of Great Falls. Here wells range from 20 to 435 feet in depth and the water table is at 1 foot to 187 feet. One well yields a small flow and the rest yield about 5 to 50 gpm.

The Madison Formation yields fair to poor water from wells in other widely scattered areas of Montana. Most of these wells were drilled originally as oil tests and produce water by artesian flow.

In the Cut Bank area, Madison water is unpotable, as shown by an analysis that listed more than 7,000 ppm total dissolved solids.

A well near Fort Benton in Chouteau County flowed more than 200 gpm of strongly mineralized water from the Madison Formation.

In Blaine County south of Chinook, Madison water was used at the rate of 70,000 barrels per month for secondary recovery operations in the Bowes Field from December 1966 through April 1967. Madison water was also reported as being used for secondary recovery of petroleum in the Elk Basin Field in Carbon County. A potential for large flows from the Madison at depths of 700 to 1,400 feet is reported in T. 7 and 8 S., R. 24 E., Carbon County.

In Big Horn County an abandoned oil test produced an initial flow of 15,000 gpm from the Madison Limestone from a depth of about 4,000 feet. This water is reported as being suitable for continual irrigation of alfalfa on permeable, well-drained soils because of its low salinity, although its calcium sulfate content makes it unpotable.

In the Bluewater Springs area of Carbon County, the top of the Madison Formation is at a depth of about 1,000 feet, and a well 1,250 feet deep is potentially capable of producing water at a rate of more than 3,000 gpm. The water quality is assumed to be good to fair for domestic use, because dissolved solids range from 1,000 to 1,500 ppm.

Streams draining the Big Snowy and Little Belt Mountains lose water by infiltration into cavernous zones as they cross Madison Limestone outcrops. It has been estimated that as much as 250 cubic feet of water per second is supplied to the Madison Limestone in the Little Belt Mountains.

Few wells draw water from the Madison Limestone in the Judith Basin. Analyses show the water to be of excellent quality in one well 140 feet deep and of poor quality for domestic use in one well more than 4,000 feet deep.

Many attempts to obtain water from the Madison Limestone in or near the outcrop zone have been unsuccessful because the water table is very deep in many places.

The Madison Limestone is a potential source of large amounts of ground water, some of it under artesian pressure, but development will require test drilling. Recovery of some of this water would certainly be worth considerable effort and expense.

A flow in excess of 1,400 gpm is reported from a well in the Madison Limestone at a depth of 3,500 feet in Phillips County, southeast of Malta. Depths to the Madison aquifer range from 3,100 to 4,500 feet in Phillips County.

Amsden Formation

The Amsden Formation, of Late Mississippian and Early Pennsylvanian age, yields good to fair water to a few wells in the Judith Basin and is considered an excellent aquifer in some areas of Big Horn County where large yields have been reported. Strongly mineralized water is to be expected from the Amsden except in areas close to the mountains. The Amsden in Big Horn County consists of about 250 feet of sandstone, shale, and limestone with cavernous porosity. In Carbon County the thickness of the Amsden is about 150 feet, and the unit is an excellent water source in the Bluewater Springs area where it shares a common aquifer with the overlying Tensleep Sandstone. A well about 800 feet deep in the Amsden-Tensleep aquifer produces 3,700 gpm of good water; the specific capacity is 26 gpm/ft.

Tensleep Sandstone

The Tensleep Sandstone, of Pennsylvanian age, consists of as much as 100 feet of sandstone and thin siltstone and limestone beds in Big Horn County and is 100 to 200 feet thick in Carbon County. In Big Horn County, initial flows of 2,000 gpm and sustained flows of 200 gpm of slightly mineralized water are reported from the Tensleep.

Chugwater Formation

The Chugwater Formation, of Triassic age, consists of 450 to 650 feet of sandstone and siltstone, an upper thin limestone, and thin gypsum beds in the

lower part, in Big Horn County and is 100 to 650 feet thick in Carbon County. In the Bluewater Springs area of Carbon County, the Chugwater has a potential production of 1,500 gpm of good water containing 600 to 700 ppm total dissolved solids.

In reviewing Montana groundwater reports, it is evident that a few formations such as the Fort Union, Hell Creek, Fox Hills, Judith River, and Kootenai supply water to most of the wells; large yields are most common in the Kootenai and Madison Formations.

Minor Bedrock Aquifers

In most of the reports, a few wells are referred to other formations capable of yielding small to moderate supplies of potable water, and although these wells are not of great importance on a statewide basis, they are of considerable local significance.

Bearpaw Formation

The Bearpaw Formation consists of about 1,000 feet of dark-gray to black marine shale containing local sandy lenses and concretionary zones. Because of poor quality of water and low yields, the Bearpaw Formation is a poor aquifer, and few wells are tabulated from this formation.

In Big Horn County north of Hardin wells in the Bearpaw Formation range from 70 to 225 feet in depth and the water table is at 3 to 40 feet. The water from several of these wells is unpotable, although they are listed as being used for stock and domestic purposes. Yields are ½ to 5 gpm.

Similar descriptions fit Bearpaw wells in other areas from which a few wells are reported in Golden Valley, McCone, Musselshell, Rosebud, Treasure, and Yellowstone Counties.

Claggett Formation

The Claggett Formation consists of about 500 feet of gray and brown shale, sandy shale, and sandstone. Sandstone beds in the Claggett are important aquifers only in the Wheatland Basin in the general vicinity of Harlowton. Wells range from 60 to 215 feet in depth and yield as much as 600 gpm of fair quality water in the Harlowton municipal wells. Yields from other wells are generally low, but a few wells yield small flows. The Claggett also supplies water to a few wells in Fergus, Golden Valley, Meagher, Musselshell, and Yellowstone Counties, but in general the Claggett is not an important aquifer except as stated above.

Livingston Formation

The Livingston Formation consists of about 14,000 feet of andesitic sandstone and conglomerate, and andesitic shale that was derived chiefly from the weathering of volcanic rocks. The Livingston Formation was deposited over a long span of time, and some of the rock constituents common to the Livingston Formation are contained in the adjacent rock units of the lower part of the Fort Union, Hell Creek, Bearpaw, Judith River, Claggett, and upper part of the Eagle Formation.

The Livingston Formation yields small amounts of water to a few wells in northern Sweet Grass County from depths of about 60 feet for stock and domestic use. The quality is excellent, judged on the basis of analyses showing less than 500 ppm total dissolved solids from springs.

In Meagher County a few wells 60 to 100 feet deep provide small yields from the Livingston Formation. The water table in these wells is usually about 30 to 40 feet below the land surface.

Large yields are unlikely from wells in the Livingston Formation, although one large spring in northern Park County flows about 1,500 gpm.

Wells in the Livingston Formation in northern Park County range from 23 to 850 feet in depth and the water table is at 5 to 275 feet. Yields range from 5 to 15 gpm, but one municipal well at Livingston is reported to yield 800 gpm from the Livingston Formation. The water is of excellent quality, as it contains 285 ppm total dissolved solids.

Colorado Shale

The Colorado Shale consists of about 2,000 feet of dark-gray marine shale containing thin sandstone members, especially near the base. The basal sandstone is known in some areas as the First Cat Creek. Near the middle of the basal part is a sandstone member about 200 feet thick, known as the Big Elk, which provides the water supply for the town of Two Dot from a flowing well 900 feet deep. Several other wells produce flows of about 10 gpm from the Big Elk in this area. The quality of the water is reported as good, because it contains 910 ppm total dissolved solids.

Flows have been reported from the First Cat Creek in Golden Valley and Musselshell Counties at depths of about 1,500 feet. In the Wheatland basin, the First Cat Creek (or Dakota) is a potential aquifer.

The shaly portion of the Colorado yields small amounts of strongly mineralized water in a few areas in Musselshell County, and except for the sandstone members, this formation is a poor aquifer.

In Judith Basin County and adjacent areas of Fergus County, the Telegraph Creek Formation is mapped with the Colorado Shale and the two formations are referred to as though they were one unit. Most of the wells range from 12 to 136 feet in depth and the water table is at 2 to 78 feet. Yields are generally low, 2 to 5 gpm, and some wells flow 2 to 20 gpm.

Water from the Colorado Shale in the Judith Basin contains about 500 to 17,00 ppm total dissolved solids, and the quality is excellent to permissible for domestic use.

In the Cascade-Ulm area of Cascade County, the basal sandstone of the Colorado Shale consists of about 200 feet of sandstone containing a middle shale unit called the Flood Member of the Blackleaf Formation. The upper sandstone yields small amounts of good water to wells on pump, and flows of good water at rates of 4 to 40 gpm are obtained from the lower sandstone unit.

Precambrian Aquifers

In the Kalispell Valley, a few wells produce water from the Precambrian rocks of the Belt Series. Twenty-six wells south of Kalispell range from 35 to 467 feet in depth and yield .5 to 33 gpm; a few of the wells flow at rates generally less than 1 gpm. The specific capacities range from .01 to 1.3 gpm/ft. The quality is excellent with respect to total dissolved solids, but excessive nitrate content in at least one well demonstrates the possibility of pollution.

Springs

Springs are mentioned in several Montana groundwater reports, and their importance is shown by the location of many ranch headquarters and towns close to these dependable supplies of potable water.

Springs occur in association with every large gravel terrace in Montana, in most areas of igneous rocks, and in every permeable sedimentary rock that is exposed by erosion to an area of recharge.

Springs represent natural discharge from a groundwater reservoir. The reservoir is continually replenished by downward percolation of precipitation, and the spring will flow so long as recharge is provided. If recharge is curtailed by drought, or if wells tap the same reservoir and remove more water than is replaced annually by precipitation, the spring may cease to flow.

Springs at the edge of stream terraces, which depend entirely on precipitation for recharge, may cease to flow during a drought. If the terrace is irrigated, infiltration of irrigation water will supply several times as much recharge as precipitation, and the spring will probably flow the year round. Under natural conditions most springs that receive recharge from snow fields on the flanks of mountain ranges will be perennial springs.

In the Kalispell area, springs in sand and gravel discharge 200 to 15,000 gpm or more. Chemical analyses show the water from two of these to be of excellent quality.

Northwest of Eureka in Lincoln County, four springs along the western edge of the Tobacco Plains issue from sand and gravel in Pleistocene glacial lake deposits. The spring's average flow ranges from about 450 gpm for the smallest spring to 4,500 gpm; the flow of the largest spring varies from 3,700 gpm in winter to 7,600 gpm in summer. The water from all four springs is of excellent quality, total dissolved solids being less than 150 ppm.

In the Cascade-Ulm area of Cascade County, individual springs yield as much as 100 gpm from the Missouri River alluvium.

Springs flow from fractures in igneous rocks in several areas in Montana. On the Fort Belknap Indian Reservation perennial springs discharge as much as 150 gpm from fractured shonkinite sills. Four springs discharging from basalt sills provide excellent water for part of the municipal supply at Cascade, Montana. Hunter's Hot Springs, near Springdale in Park County, yield about 1,500 gpm at 142°F from fissures in an igneous dike in the Livingston Formation.

Springs occur in all the bedrock formations exposed at the surface in Montana.

In eastern Montana the flat-lying Fort Union Formation provides spring water from coal and sandstone layers. The Hell Creek and Hell Creek-Fox Hills aquifers give rise to many springs, especially on the Cedar Creek anticline where springs flow into Cabin Creek and also into the Yellowstone River. Springs are common even in formations that do not normally yield adequate amounts of water

to wells; for example, springs occur in the Bearpaw and Claggett Formations and in the Colorado Shale.

Springs in the Judith River Formation commonly yield small flows, quality running the full range from excellent to unusable.

Springs in the Eagle Sandstone, or the Virgelle as it is called in western Montana, yield as much as 50 gpm in the Cut Bank area. In the Cascade-Ulm area, springs are known that yield 10 to 15 gpm of good water from the Virgelle.

The Kootenai Formation probably gives rise to more springs than any of the other bedrock aquifers. In the Judith Basin, numerous springs rise from the Kootenai rocks, more than from any other bedrock source, although springs in the unconsolidated aquifers are more numerous and generally provide larger yields. The average yield of the Kootenai springs is less than 10 gpm of good water for domestic use.

Other formations that give rise to many springs in the Judith Basin are the Amsden, Morrison, and Telegraph Creek.

Individual springs flow 10 to 30 gpm of excellent quality water from the Amsden in Big Horn County.

In Valley County, springs occur in gravels of the Flaxville Formation and in the bedrock formations. Yields range from 5 to 200 gpm, 10 to 20 gpm yields being most common. Quality of the water is good to fair.

On a statewide basis more than 18,000 springs are listed on an inventory by the Montana Bureau of Mines and Geology, compiled from lists of springs recorded under Montana water laws. Undoubtedly many more occur that have not been recorded. Table 3 provides a list of springs recorded in Montana as of December 31, 1967.

Springs are a valuable asset to farmers and ranchers, sparing them the expense and often the uncertainty of developing wells.

Several springs that yield large flows occur in Montana. Giant Springs near Great Falls is the largest; its flow is about 600 cubic feet per second. Giant Springs is one of several in the state that supply water for fish hatcheries. In some of the early groundwater reports, it was assumed that the Missouri River was the source of the water for these springs. Test drilling and chemical analysis of the water has led to the belief, currently held by some workers in the groundwater field, that the water reaches the springs through channels in the Madison Limestone and rises to the surface through fractures in the overlying Kootenai sandstone.

Big Springs near Lewistown yields about 140 cubic feet per second. The water issues from fractures in sandstone of the Ellis Formation and is probably supplied from the underlying Madison Limestone.

Mammoth Spring or Big Spring near Toston discharges water from a talus-covered slope that overlies the basal part of the Amsden Formation. The water is believed to reach the spring through channels in the Madison Limestone. The spring yields water at a rate of 60 cubic feet per second, part of which is diverted for irrigation.

Warm Springs near Lewistown discharges about 140 cubic feet per second of good water at a temperature of 68°F. Warm Springs is probably the largest of the springs in Montana that are notable for their warm water.

Many thermal springs discharge water at much higher temperatures than 68°F. At Bozeman Hot Springs the temperature is reported at 140°F. Flows from other thermal springs in Montana range from 25 to 15,000 gallons per minute. Forty hot springs in Montana are listed in the U. S. Geological Survey Water Supply Paper 679B, "Thermal Springs in the United States." About half of these have been developed as resorts and many others have swimming pools.

In the Bluewater Springs area of Carbon County, numerous springs issue from the Tensleep Sandstone and flow 1 to 2,000 gpm. The Chugwater Formation also gives rise to many springs; their flows range from 1 to 3,700 gpm.

Analyses are available only for Tensleep water, which ranges from good to permissible for domestic use and permissible to doubtful for irrigation. Spring water from both the Tensleep and Chugwater is used for domestic, stock, and irrigation purposes.

References:

Large Springs in the United States, USGS Water-Supply Paper 557, Meinzer, O. W., 1927.

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Thermal Springs in the United States, USGS Water-Supply Paper 679B, Stearns, N. D., et al., 1935.

Geology and Water Resources of the Bluewater Springs Area, Carbon County, Montana: USGS Water-Supply Paper 1779-J, 1964.

MONTANA BUREAU OF MINES AND GEOLOGY, DECEMBER 31, 1967
WATER WELL INVENTORY

COUNTY	A—Conditioning	C—Commercial	D—Dewatering	F—Fire Protection	H—Domestic	I—Irrigation	N—Industrial	P—Public Supply	S—Stock	R—Domestic and Stock	T—Institutional	U—Unused	X—Unknown	TOTAL
Beaverhead		10			321	50	8	35	219	173	2	5	1	824
Big Horn		3			84	20	1	8	221	146	2		4	489
Blaine					70	9	2	3	266	170	9	2	12	543
Broadwater		4			90	31	1	7	157	107	2	8	4	411
Carbon				1	102		4	5	40	29	1	1	4	187
Carter					41	4	1	2	584	94		1	5	732
Cascade	1	15		1	528	50	15	24	232	374	10	7	11	1,268
Chouteau		2		1	128	11		19	301	346		6	7	821
Custer		12		4	120	37	5	6	502	233	4	2	5	920
Daniels					115	12	1	4	164	163	2	6	3	470
Dawson	1	10			233	33	9	16	566	254	2	3	22	1,149
Deer Lodge	2	3		3	444	33	8	4	22	42	3	3	6	573
Fallon		1			34	5	5	7	450	224		3	11	740
Fergus		4			231	21	7	7	408	396	1	4	35	1,114
Flathead	1	7		3	1,027	61	27	18	31	541	3	3	9	1,731
Gallatin	2	31			979	87	11	28	189	601	7	6	18	1,959
Garfield		2			125	4	3	1	568	206	1	11	7	1,018
Glacier		10			110	10	25	8	79	155		2	8	407
Golden Valley					29	5			243	83				360
Granite		10			183	5	1	2	20	73	1		15	310
Hill		6			326	17	7	13	205	220	5	11	16	826
Jefferson		5			127	21	5	17	76	73	9	6	5	344
Judith Basin		3			118	15	1	9	240	153	1	2	8	550
Lake		10			356	27	7	9	44	371	6	2	6	838
Lewis & Clark		38		1	649	81	9	29	115	202	4	6	30	1,164
Liberty					94	2		4	107	86		4	2	299
Lincoln		8			447	11	10	9	5	69	4		19	582
Madison		6	1		350	18	4	28	217	211	4		10	849
McCone		1			74	4	5	1	330	164	2	1	4	586
Meagher		1			46	4	4	7	50	38			2	152
Mineral		5			95	7	4	9	4	14	1			139
Missoula	1	21			1,095	65	38	43	18	159	12	2	10	1,464
Musselshell		1			64	10	1	3	798	90		3	8	978
Park		9			256	19	9	8	55	168	1	11	7	543
Petroleum					19	11	52	2	140	51				275
Phillips		1			193	13	2	12	449	406	1	6	2	1,085
Pondera					43	3		14	74	147	1	2	1	285
Powder River		3			177	20		5	1,524	202	1	4	12	1,948
Powell		2			208	13	7	6	40	93		1	1	371
Prairie					76	5	6	5	429	98	3	2		624
Ravalli	4	3		2	896	176	13	12	131	477	6	2	15	1,737
Richland	3			1	201	10	6	12	664	237	1	7	11	1,153
Roosevelt					122	29	3	17	249	233	4	3	7	667
Rosebud				1	89	7	12	5	577	177	5	3	5	881
Sanders		2		2	197	73		9	60	173			7	523
Sheridan		16			99	4		9	172	247	1	1	4	553
Silver Bow				1	175	11	16	8	22	56	1		5	295
Stillwater		2			226	9	4	6	352	152	3	7	10	771
Sweet Grass					82	4		1	156	143	2		2	390
Teton		4		1	328	51	5	28	231	270	3	5	5	1,031
Toole		1			34	6	12	14	139	109			1	316
Treasure					24			2	204	54				284
Valley		8			266	21	4	32	440	397	3	7	15	1,193
Wheatland		2		1	54	8	1	4	279	69		3	5	426
Wibaux		1			24	6	6	4	321	205	4	13	5	589
Yellowstone	2	10	1		353	148	15	8	571	431	6	5	19	1,569
TOTAL	17	293	2	23	12,977	1,417	402	608	14,846	10,945	144	192	446	42,306

TABLE 3

MONTANA BUREAU OF MINES AND GEOLOGY, DECEMBER 31, 1967
SPRING INVENTORY

County	A—Conditioning	C—Commercial	D—Dewatering	F—Fire Protection	H—Domestic	I—Irrigation	N—Industrial	P—Public Supply	S—Stock	R—Domestic and Stock	T—Institutional	U—Unused	X—Unknown	TOTAL
Beaverhead					4	41			118	15		1	87	266
Big Horn					4	9			214	12			40	279
Blaine									62	1			121	184
Broadwater					5	46			95	9			51	206
Carbon					29	24		1	430	36		1	264	785
Carter					2	3		3	219	13			27	267
Cascade					27	49	1	3	504	78			383	1,045
Chouteau				1	10				141	16		2	147	317
Custer		1			1	1			40	1			54	98
Daniels						9			125	7			9	150
Dawson					1	12			380	9			306	708
Deer Lodge					18	23	1	1	24	8			16	91
Fallon						2		1	114	2			109	228
Fergus					12	49		1	411	269	1		32	775
Flathead					59	40	8	1	54	27		1	67	257
Gallatin		2			29	79			173	38		3	233	557
Garfield									67	6			72	145
Glacier					4				96	13			66	179
Golden Valley									117				80	197
Granite					14	42	3		133	3			164	359
Hill					8	7			55	5			28	103
Jefferson					10	37		8	128	12			56	251
Judith Basin		1			10	2			156	19			103	291
Lake					65	66	6	2	131	28		1	73	372
Lewis & Clark		6			25	31			403	22			107	594
Liberty					1	6			37	6			16	66
Lincoln					15	5	1	1	5	16			4	47
Madison		5			26	74	4		299	40			99	547
McCone									56				28	84
Meagher					9	175			210	15			91	500
Mineral		1			10	2		1	1	1				16
Missoula		6			45	71			118	23			109	372
Musselshell						18			126	4			81	229
Park		7			46	80			428	102			73	736
Petroleum						3		2	28	1			9	43
Phillips		1			2				50	11			30	94
Pondera						9		1	17	2			28	57
Powder River									273	1			4	278
Powell		7			200	73	11	3	119	105		1	32	551
Prairie					1	1			111	64			20	197
Ravalli		2			31	108		1	232	36			137	547
Richland					3	1			112				114	230
Roosevelt					1	4		1	49				14	69
Rosebud					3	3			132	4			199	341
Sanders					36	40			112	16			131	335
Sheridan					5				46	2			51	104
Silver Bow					31	23	6		128	52			7	247
Stillwater					10	81			361	40			215	707
Sweet Grass		2			26	48	1	5	784	37			509	1,412
Teton				9	42				165	11			49	276
Toole					6	16		36	101	7		1	10	177
Treasure					7				56	1			57	121
Valley						15			314	9			28	366
Wheatland					3	42			335	27			21	428
Wibaux									3					3
Yellowstone					3	4			91	5			42	145
TOTAL		41		10	899	1,474	42	72	9,289	1,287	1	11	4,903	18,029

Quality of Groundwater

The quality of groundwater is generally excellent to good in western Montana, where the bedrock is well consolidated and leaching of soluble minerals, such as carbonates, sulfates, and chlorides, is limited. Water in the unconsolidated aquifers of the intermontane valleys is normally excellent and is the most important water supply in the state, but water of poor quality is found in some places. This is due to mixing with hot, strongly mineralized water from underlying formations in certain areas of the Gallatin Valley. In other areas it is probably due to the relative stagnation of water in the deeper zones, and thus being in contact with soluable minerals for longer periods.

Groundwater in the shales of central and eastern Montana is generally of poor quality, because greater amounts of soluble minerals are available in the rocks, and slower movement of water allows longer contact time between the water and the soluble minerals. Limited recharge is also a contributing factor.

The unconsolidated aquifers in the central and eastern parts of the state show a deterioration in quality for the same reasons stated above because the weathering products of the softer formations make up a greater proportion of the alluvial deposits. The alluvial aquifers that discharge by underflow have at least some circulation and recharge and thus contain better quality water than those in which the water is essentially trapped unless tapped by wells.

The quality of groundwater in the unconsolidated aquifers deteriorates downstream from irrigated areas, because salts from the soil are taken into solution by the water. Some of this water, with its added load of dissolved solids, infiltrates the ground water reservoir with a resulting deterioration in quality.

It has been noted in several reports that water in a sandstone is of better quality in areas where it is not overlain by shale. This is due for the most part to the large surface area capable of receiving recharge. Only limited recharge is available to a sandstone with few surface exposures and overlain in large areas by a relatively impermeable shale, with a high content of soluble minerals. In such areas recharge is inadequate to improve the quality of the water.

Water from shallow depths in the Fort Union aquifers is noted for being hard and relatively low in dissolved solids, while water from deeper horizons is generally soft, but high in mineral content.

Quality of groundwater in the relatively impermeable glacial till that covers an area of thousands of square miles in north-central and northeastern Montana is generally poor. Water in the glacial deposits that are composed chiefly of sands, gravels, and silts, such as kames, eskers, and outwash channels is usually excellent to good.

Water Standards

Standards for drinking-water supplies have been established by the U. S. Public Health Service, and the Montana Department of Health has adopted these or comparable standards. Standards are determined on the basis of bacteria content, physical characteristics, such as color, taste, and odor, and chemical constituents.

Naturally, harmful bacteria should not be present in drinking water. The Montana State Department of Health provides information on properly safeguarding wells and springs from pollution, as well as methods of purifying wells.

Color, odor, taste, and turbidity problems in drinking water vary considerably and are important factors in domestic water supplies. Ordinarily if simple means cannot be used to correct these problems, another source of water must be found.

Quality of water for irrigation should be discussed with the local County Agricultural Agent. Suitability of water for irrigation is subject to many variables as to type of crop and type of soil, as well as chemical constituents in the water. Sodium and boron are extremely critical in irrigation water. A numerical classification is used in this report to express relative suitability of water for irrigation:

Numerical class	Description
1	Excellent, for all crops on all soil types
2	Good, usable for most crops and soil types
3	Fair, usable for short periods only on certain crops and soil types
4	Poor, usable for certain crops and soil types only under emergency conditions
5	Unusable for irrigation

Quality of water for industrial use has to be determined on an individual basis. If there is any

chance of variation in quality of the water supply, close control on quality should be maintained.

In the charts, maps, and summaries used in this report to present groundwater information, the quality of water for domestic use is classified numerically as shown below.

Numerical class	**Description**
1	Excellent, conforms to U. S. Public Health standards, less than 500 ppm total dissolved solids.
2	Good, conforms to standards but contains 500 to 1,000 ppm total dissolved solids.
3	Permissible, contains no harmful elements in excess of standards but may contain as much as 2,500 ppm total dissolved solids.
4	Unfit for domestic use, but usable for special purposes, (2,500 to 3,500 ppm).
5	Unusable (more than 3,500 ppm).

Abbreviations used in this report to indicate use of groundwater are:

D—domestic

Ind—industrial

Irr—irrigation

Mun—municipal

S—stock

References:

Study and Interpretation of the Chemical Characteristics of Natural Water, USGS Water-Supply Paper 1473, Hem, J. D., 1959.

Groundwater Hydrology, Todd, D. K., John Wiley & Sons, Inc., 1959.

CONCLUSIONS

Plans for continued acquisition of information pertaining to groundwater are already in existence. The need for further information continues to grow. Formerly, information was sought only after it was apparent that a groundwater source was desirable or necessary, as one step in an agricultural, municipal, or industrial long-range program.

Well-planned and executed groundwater investigations can be instrumental in the choice of agricultural and industrial sites, and with the trend toward decentralization of industry, advance knowledge concerning groundwater availability at several locations could be of great importance to the further development of Montana's resources.

Implementation of plans for new groundwater investigations is limited by available funds, and it may be more profitable to gather minimum data at several locations rather than to make more detailed studies at a few.

Currently nine groundwater studies are underway in Montana. Four of these are strictly federal projects and five are cooperative projects involving both state and federal funds.

Conjunctive use of surface water with groundwater resources has been considered in recent years. Conjunctive use can provide water for additional irrigated acreages in Montana after the details are worked out. Planning for conjunctive use calls for the use of surface water during the season of high runoff on all lands under irrigation and later on the use of ground water in areas where it is readily available. At this time the surface water would be diverted to the irrigable lands that lack a groundwater supply. Similarly, conjunctive use could extend the time during which a supply of water could be made available for other industrial applications.

Other planning is concerned with drought periods when use of groundwater might well exceed normal recharge, thus partially depleting the water in storage. During subsequent wet years of increasing recharge, levels in the groundwater reservoir would be restored to optimum. In this manner, the groundwater reservoir could be used for storage of flood flows.

Although a great deal of groundwater information has already been assembled in Montana, there are still vast areas that are almost untested. The plans and programs already projected by the Montana Water Resources Board, the Montana Bureau of Mines and Geology, and the U. S. Geological Survey call for early investigations in these areas where pertinent data are still needed. After these plans are put into action, the resulting benefits will begin to show in Montana's agricultural and industrial growth.

Abbreviations

ac-ft	acre feet
ac-ft/yr	acre feet per year
gpd/ft	gallons per day per foot
gpm	gallons per minute
gpm/ft	gallons per minute per foot
ppm	parts per million
psi	pounds per square inch
ss	sandstone

LIST OF ABBREVIATIONS, DEFINITIONS, AND SYMBOLS

Definitions and Symbols

Alluvium is stream deposited gravel, sand, silt, and clay, mostly unconsolidated. Some authors apply the term to lake deposits of the same materials.

An **aquifer** is a formation, or group of formations, that will yield usable quantities of water. The unconsolidated aquifers are not given formation names, but they are included here.

In an **artesian aquifer** the water rises in a well above the point at which it is found in the aquifer.

The **coefficient of storage, S,** of an aquifer is the volume of water released from or taken into storage per unit surface area of the aquifer, per unit change in the component of head normal to that surface.

A **confining bed** overlies or underlies an aquifer and because of its low permeability relative to the aquifer, impedes or prevents loss of water from the aquifer.

Drawdown, s, is the lowering of the water level in a well as a result of pumping water from the well or from an adjacent well.

Evapotranspiration is the combined discharge of water to the air by evaporation and plant transpiration.

F°, degrees Fahrenheit.

A **flowing well** is an artesian well through which water is forced above the land surface by pressure in the aquifer.

Permeability is the capacity of an aquifer to transmit water.

The **water table** is the upper surface of the zone of saturation, except where that surface is formed by an impermeable layer. The water at the water table is under atmospheric pressure.

A **water table aquifer** is one that is not confined at its upper surface.

For other definitions see the section of this report entitled "Explanation of charts and area summaries."